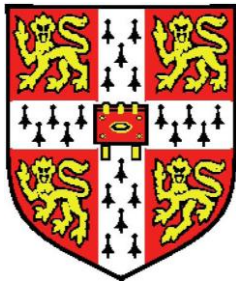


# A New Infrastructure Demand Model for Urban Business and Leisure Hubs - a case study of Taichung

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## **Abstract**

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By Hsin-tzu Ho

Over the last few decades there has been a gradual transformation in both the spatial and temporal patterns of urban activities. The percentage share of non-discretionary travel such as morning rush-hour commuting has been declining with the increased income level. Discretionary activities appear to rise prominently in urban business and leisure hubs, attracting large volumes of crowds which in turn imply new and changed demand for building floorspace and urban infrastructure.

Despite impressive advances in the theories and models of infrastructure demand forecasting, there appear to be an apparent research gap in addressing the practical needs of infrastructure planning in and around those growing urban activity hubs. First, land use and transport interaction models which have to date been the mainstay of practical policy analytics tend to focus on non-discretionary activities such as rush-hour commuting. Secondly, the emerging activity based models, while providing significant new insights into personal, familial activities, especially the discretionary travel, are so data hungry and computing intensive that they have not yet found their roles in practical policy applications.

This dissertation builds on the insights from above schools of modelling to develop a new approach that addresses the infrastructure planning needs of the growing urban hubs while keeping the data and computing realistic in medium to high income cities. The new model is designed based on an overarching hypothesis that considerable efficiency and welfare gains can be achieved in the planning and development of urban business and leisure hubs if the infrastructure provisions for discretionary and non-discretionary activities can be coordinated. This is a research theme that has been little explored in current literature.

The new infrastructure demand forecasting model has been designed with regard to the above hypothesis and realistic data availability, including those emerging online.

The model extends the framework of land use transport interaction models and aim to provide a practical modelling tool. Land use changes are accounted for when testing new infrastructure investment initiatives and especially the road and public transport loads are assessed throughout all time periods of a working day.

The new contribution to the modelling methodology includes the extension to the land use transport interaction framework, the use of social media data for estimating night market activity distribution and a rapid estimation of road traffic speeds from Google directions API, and model validation. Another new contribution is the understanding of the nature and magnitude of future infrastructure demand through assessing three alternative land use scenarios: (1) business as usual, (2) inner city regeneration for a major business hub around the night market, and (3) dispersed suburban growth with distant subcentres. The model is able to assess the implications for future infrastructure demand and user welfare through discerning the distinct discretionary and non-discretionary activity patterns.

Key words: Discretionary travel demand, 24-hour traffic modelling, social media data, congested link speed estimation, integrated land use and transport model



## **Declaration**

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University of similar institution except as declared in the Preface and specified in the text

It does not exceed the prescribed word limit for the relevant Degree Committee.

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## **List of Abbreviations**

CECI	China Engineering Consultants Incorporated
DORTS	Department of Rapid Transit Systems
GIS	Geographic information system
GLA	Greater London Authority
HBE	Home Based Education
HBO	Home Based Other
HBW	Home Based Work
LUTI	Land use and transport interaction model
MOTC	Ministry of Transportation and Communications
NHB	Non Home Based
O-D	Origin-Destination

## **Chapter 1 INTRODUCTION**

Over the last few decades there has been a gradual transformation in both the spatial and temporal patterns of urban activities. While the total amount of movements of people and goods rises with income, the percentage share of non-discretionary travel such as morning rush-hour commuting has been declining. Urban business and leisure hubs in the cities that cater for a wide variety of discretionary activities such as impromptu business, social and leisure gatherings appear to rise prominently, attracting large volumes of crowds which in turn imply new and changed demand for building floorspace and urban infrastructure.

In most cities in the world, while the total amount of movements of people and goods rising with income, the percentage share of non-discretionary travel has been in decline. In London, for instance, work related travel (both commuting and on work business) now accounts for only 28.8% of trips made by Londoners on an average weekday while leisure trips have increased by 44% over the period between 2005/2006 and 2013/2014 and many of this increased travel demands come from people who undertake night time activities (Transport for London, 2014; 2015). In many cities, business and leisure hubs have brought prosperity and vitality to the urban life and contributed to improved productivity and quality of life due to the urban agglomeration effects. However, those urban hubs are usually located in the densest parts of the cities so any rise in activities and travel in those areas may result in congestion and overcrowding which may translate into high property and goods prices and even inefficiency and social exclusion in the long term if these issues are not addressed properly in the time of need. The need for infrastructure expansion and enhancement for addressing these issues is obvious. However, they are costly and difficult to achieve in those dense urban areas without careful coordination and suitable planning tool.

### **1.1 Objectives**

Given the increasing evening congestion problems shown in big urban areas and due to current lack of modelling capacity for coordinating discretionary and non-discretionary activities, this dissertation aims to investigate the cost-effective development of practical planning to this end. Thus, the specific objectives of the research are to:

(1) carry out a comprehensive review of the existing methods for forecasting travel demand,

- (2) construct a model aimed at improving current approach to forecasting evening travel,
- (3) to implement the model for a case study area with active night economy, and
- (4) identify areas of methodological and data improvements to make adequate quantification where such evidence is lacking

## **1.2 Methodology**

This new tool is built on the MEPLAN framework, as a new integrated land use and transport model whose model structure has been extended to accommodate additional modelling dimensions that have rarely featured in existing models. More specifically, the model incorporates new components for both discretionary and non-discretionary travel demand over all time periods of the day. To overcome the data problems that have hampered the previous attempts of a similar kind, the model makes use of new social media data which serves as an input for the land use module of the integrated model. This makes it possible to consider the interactions between transport and land use activities that underlie the rarely modelled discretionary activities. In addition to the social media data, our model makes a full use of the Population Census data (Taiwan Directorate-General of Budget, Accounting and Statistics, 2010), government statistics for tourism industry (Tourism Bureau of Taichung, 2014), Taichung metropolitan area road network planning report (China Engineering Consultants Incorporated [CECI], 2009) and the transport network and trip ends data from the TransCAD model accompanying the report, Taichung household travel survey (Department of Rapid Transit Systems [DORTS], 2016), Google Map Directions, and Feng-chia survey (Lee, Lin, & Hsieh, 2015) in the case study area.

It should be noted that although this dissertation only makes use of social media data to estimate discretionary travel demand at the evening and night times due to data limitations and time constraints, the data collection and analysis techniques and the model estimation methods for discretionary travel are transferrable to estimate discretionary travel occurring during other time periods, such as inter peak hours. Also, due to the time and data constraints, the travel demand is estimated based on projected land use activity distributions rather than a comprehensive land use model. This is to say that the case study focuses on examining the traffic and transport issues for this dissertation without exploring the feedback of transport improvement on land use patterns. Notwithstanding the choice of model specification for the case study, the wider

economic and land use factors are included in the model design in such a way that the assessment of wider economic and social impacts can be incorporated as part of further work.

### **1.3 Choice of case study**

Night time activities continue to grow in many parts of the world. Many Asian cities, in particular, have the tradition that the residents go to the night market as part of social life. Some of the night markets even transform into major tourist spots of an international reputation, often supposing the fame of major centres of night life in Europe or North America. For our study, choosing a case study which is informative regarding forecasting discretionary travel during the non-peak modelling period is important.

Taichung is the third largest city in Taiwan among Taiwan's five special municipalities with a population of 2,720,000 people and it is in many ways a typical example of a large number of medium to high income provincial cities in the world. It boasts an arguably the biggest night market destination in Taichung and is recorded to be the most visited tourist attraction by international tourists in Taiwan (Taiwan Tourism Bureau, 2015a). Other night time activities dotted around the city attracts both local residents and tourists across East and South East Asia. By contrast, in the new urban plan to 2041, which anticipates a significant population and income growth, there has been little effort to plan or coordinate the provision of the urban infrastructure of the new city centre, subcentres and the night market areas. To this end, Taichung is chosen to be the case study area of the research.

### **1.4 Summary**

This thesis is constructed as following:

1. Chapter 1 gives the general background and introduction;
2. Chapter 2 offers a literature review;
3. Chapter 3 describes the methodology of land use and transport model, model calibration process;
4. Chapter 4 provides a case study of operationalising the land use and strategic transport model for the case study area of Taichung, including the social media data collection and application, congested link speed estimation using Google MAP Directions API, and the examination of the networks;

5. Chapter 5 explores the application of the model and present the results of the Existing 2013, BAU 2041, RaSnAS 2041 and RS 2041 scenarios;

6. Chapter 6 draws conclusions and proposes topics for future study.

## **Chapter 2 LITERATURE REVIEW**

### **2.1 Overview**

Most metropolitan planning organisations employ the conventional trip based four step model (de Dios Ortuzar & Willumsen, 2011). In this type of model, trips outside the AM peak period are usually not considered and therefore leisure trips tend to be largely omitted from the model. Another approach, the activity-based approach, which has been the result of increasing interest in travel behaviour research, considers travel needs as a result of an individual's or a firm's desire to participate in activities at different geographical locations at different times (Jones et al., 1990; Bhat, 2012). This kind of approach simulates activity-chains rather than trips and thus leisure trips made in a day are incorporated explicitly into the activity-chains.

The above two approaches are not able to capture the travel behavioural change in the long term because the models do not consider the impact of the transport system on land use which may affect people's decisions on housing and a firm's decision to locate the business and eventually drive a shift in people's choice in travel (Echenique, 2004).

Meanwhile the increasing use of social media and the use of smart phones, offer us a new way to observe the dynamics of urban transport and land use. Social media has opened up opportunities to collect crowd-sourced information on individuals' footprints relating to leisure activities that are not easily captured in traditional household travel surveys. Traffic data collected by GPS-enabled smart phones, prevalent in most cities nowadays, provides speed information on large numbers of roads which is again difficult to obtain with restricted resources.

The following sections provide a review of urban models to form a basis for modelling enhancement in the context of this research. Firstly, travel demand models will be reviewed and followed by the most relevant operational land use and transport interaction models.

### **2.2 Conventional four-stage transport models**

The fundamentals of transport modelling were developed during the 1950s. That period had seen rapid increases in car use followed by major investments in new road infrastructure. This resulted in the development of an aggregate approach called the sequential four-step transport model for evaluating performance of transportation



systems and large-scale transport infrastructure projects. This approach starts by dividing a study area into zones. The size and number of the zones is determined based on the modelling purpose and the precision required. For each zone, base year data on demography such as the size of different population types and land use (economic activity) such as employment, shopping floor space, educational institutions and recreational facilities is needed. Also, a network which contains information on transport supply is needed. The first step is trip generation which determines the total number of trips generated from and attracted to each zone based on the demographics and land use mentioned earlier. The next step is the distribution of trips between zones which gives a trip matrix. The following step is a modal split which involves allocating trips in the matrix to different transport modes. Lastly, the trip assignment stage calculates how the trips by each transport mode will distribute onto their corresponding network.

During the 1970's transport planning shifted focus from global infrastructure developments to the travel needs of individuals. Disaggregate models such as disaggregate trip based demand models and activity based travel demand models were developed in response to the shift. Disaggregate models flourished during the 1980's and 1990's and have been applied in many projects around the world in the past 20 years. Nowadays, more disaggregate versions of four-step model continuously dominate the process of travel demand modelling. The following sections describe these models in detail.

### **2.2.1 Aggregate Models**

#### **1. Gravity model**

Aggregate models are the earliest travel demand models employing simple mathematical models, such as a gravity model. The number of trips generated from a zone was considered to be proportional to the total trip ends in the origin zone and the number of trips attracted to a zone was considered to be proportional to the total trip ends in the destination zone. Moreover, the number of trips between zones was determined by the inter-zonal impedance, i.e. the disincentive to travel as distance (time) or cost increases. Generally, the gravity model can be expressed as:

$$T_{ij} = \alpha O_i D_j f(c_{ij})$$

Where

$T_{ij}$  is the number of trips between origin zone  $i$  and destination zone  $j$

$O_i$  is the total trip ends at origins

$D_j$  is the total trip ends at destinations

$\alpha$  is a proportionality factor

$f(c_{ij})$  is a generalised function of the travel cost with one or more parameters for calibration.

## 2. Entropy maximising technique

The derivation of the gravity model from principles of entropy maximisation (Wilson, 1970) was a major accomplishment and formed the basis for many of the allocation mechanisms within spatial interaction.

Wilson proposed an approach which considers the location of services activities expressed by:

$$F_{ij} = \frac{P_i W_j^\alpha e^{-\beta c_{ij}}}{\sum_l W_l^\alpha e^{-\beta c_{il}}}$$

Where

$F_{ij}$  represents the flows (monetary flows or number of consumer) between zone  $i$  (origin, residential zone) and zone  $j$  (destination, in which the service is located)

$P_i$  is the number of consumers living in the zone  $i$ ,

$W_j^\alpha$  represents the commercial attractiveness of the zone  $j$ ,

$c_{ij}$  is the transport cost from zone  $i$  to zone  $j$ ,

$\alpha$  and  $\beta$  are modifying parameters

When flows throughout the agglomeration are defined, we obtain the demand  $D_j$ , induced by all the agglomeration in zone  $j$ :

$$D_j = \sum_i F_{ij}$$

In others models, attractiveness of a zone  $j$  is an exogenous variable, measured by number of services offered in zone  $j$ , commercial surfaces and etc. This factor defines supply of services, and the model defines the distribution of the flows of consumers in function of this supply (the distribution of the supply is given "a priori"). The great interest of the Wilson's model is to consider the supply as an endogenous variable and to model its evolution through time. It assumes that the suppliers of services are interested by the distribution of the demand, and try to adapt their behaviour to it. The system tend to come to an equilibrium between production costs, function of attractiveness  $W_j$  and income products, function of demand  $D_j$ .

### 2.2.2. Disaggregate trip-based models

This group of models explains the connection that exists between the characteristics of locations and the behaviour of decision maker. An individual is associated with a utility function ( $U_{ni}$ ), regarding the attributes of location and the properties displayed by the decision maker. Each decision maker has to make his decision from a discrete set of alternative choice options and will settle on the option with the highest utility. Since not all attributes of the location and the decision maker are observable, a random measuring strict utility ( $V_{ni}$ ), the fixed and measurable attributes of utility; and the other dealing with stochastic utility ( $\varepsilon_{ni}$ ), an error or disturbance term that reflects the unobserved attributes of a given decision. And the total utility of any alternative  $i$  is expressed by the sum of observed and unobserved components. The utility function can be expressed as follows:

$$U_{ni} = V_{ni} + \varepsilon_{ni} = \beta Z_{ni} + \varepsilon_{ni}$$

Where

$U_{ni}$  is the utility for the person  $n$  to choose alternative  $i$

$V_{ni}$  is the fixed and measurable attributes of utility for the person  $n$  to choose  $i$

$\varepsilon_{ni}$  captures the impact of all unobserved factors that affect the person's choice.

$Z_{ni} = Z(X_{ni}, S_n)$  is a vector of observed variables where  $X_{ni}$  are attributes of the alternative  $i$  and  $S_n$  are attributes of the person  $n$  ( $X_{ni}$  and  $S_n$  may interact with each other)

$\beta$  is a corresponding vector of coefficients of the observed variables

Based on the above theory, the discrete choice model is derived and the choice probability can be express by the following equation:

$$\begin{aligned}
P_{ni} &= Prob(U_{ni} > U_{nj}) \\
&= Prob(\beta Z_{ni} + \varepsilon_{ni} > \beta Z_{nj} + \varepsilon_{nj}) \\
&= Prob(\varepsilon_{nj} - \varepsilon_{ni} < \beta Z_{ni} - \beta Z_{nj}), \forall j \neq i
\end{aligned}$$

Where

$P_{ni}$  is the probability for the person n to choose alternative i

$U_{ni}$  is the utility for the person n to choose alternative i

$U_{nj}$  is the utility for the person n to choose alternative j

$\beta$  is a corresponding vector of coefficients of the observed variables

$Z_{ni} = Z(X_{ni}, S_n)$  is a vector of observed variables where  $X_{ni}$  are attributes of the alternative i and  $S_n$  are attributes of the person n ( $X_{ni}$  and  $S_n$  may interact with each other)

$Z_{nj} = Z(X_{nj}, S_n)$  is a vector of observed variables where  $X_{nj}$  are attributes of the alternative j and  $S_n$  are attributes of the person n ( $X_{nj}$  and  $S_n$  may interact with each other)

$\varepsilon_{ni}$  captures the impact of all unobserved factors that affect the person n's choice of alternative i

$\varepsilon_{nj}$  captures the impact of all unobserved factors that affect the person n's choice of alternative j

Different choice models arise from different distributions of  $\varepsilon_{ni}$  (for all i). The most popular form of discrete choice model is logit model which means the unobserved utility is distributed extreme value. The logit choice probability can be expressed as:

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} = \frac{e^{\beta Z_{ni}}}{\sum_j e^{\beta Z_{nj}}}$$

Where, as defined above

$P_{ni}$  is the probability for the person n to choose alternative i

$V_{ni}$  is the fixed and measurable attributes of utility for the person n to choose i

$V_{nj}$  is the fixed and measurable attributes of utility for the person n to choose j

$Z_{ni} = Z (X_{ni}, S_n)$  is a vector of observed variables where  $X_{ni}$  are attributes of the alternative  $i$  and  $S_n$  are attributes of the person  $n$  ( $X_{ni}$  and  $S_n$  may interact with each other)

$Z_{nj} = Z (X_{nj}, S_n)$  is a vector of observed variables where  $X_{nj}$  are attributes of the alternative  $j$  and  $S_n$  are attributes of the person  $n$  ( $X_{nj}$  and  $S_n$  may interact with each other)

$\beta$  is a corresponding vector of coefficients of the observed variables

The major limitation of these models was the missing linkages between trips. As a result, different modes of transport could potentially be assigned to a home-to-work trip and its return trip from work.

### 2.3 Activity-based models

Activity—based model offered an alternative approach by representing the demand for travel as derived from the need to conduct activities separated in space and time (Axhausen & Gärling, 1992). This type of model place primary emphasis on activity participation and patterns of activities made subject to the interdependencies with other household members within the constraint of space and time (Hägerstrand, 1970 and Chapin, 1974). Thus, this type of models predicts for a person which activities are conducted when, where, for how long, for and with whom and the mode choices they will make to complete them. Some of these models rely primarily on econometric choice models based on the theory of the utility maximisation as described above while others use rule-based decision simulations.

There are in general two types of activity-based application model:

1. Tour-based models: initial type of activity-based model is the tour-based model. This approach uses a tour, a sequence of linked trips that begins and ends at the same location such as trip maker's home, rather than a trip as the unit of analysis to capture the linkage between trips of the same tour. Although popular in the developed country cities practice, these kinds of models would be considerably more demanding in terms of data and model software requirements (Miller et al., 2005);

2. Activity scheduling models:

More recently, emphasis has shifted to activity scheduling and trip chaining behaviour of households. In the activity scheduling models, out-of-home activity schedules are explicitly generated to capture the processes of individuals implementing activity



In terms of model structure, most operational LUTI models have three main sub-models. They are land use, socio-demographic and transport models. They are either fully integrated or loosely coupled with each model during the model execution (Figure 2-2).

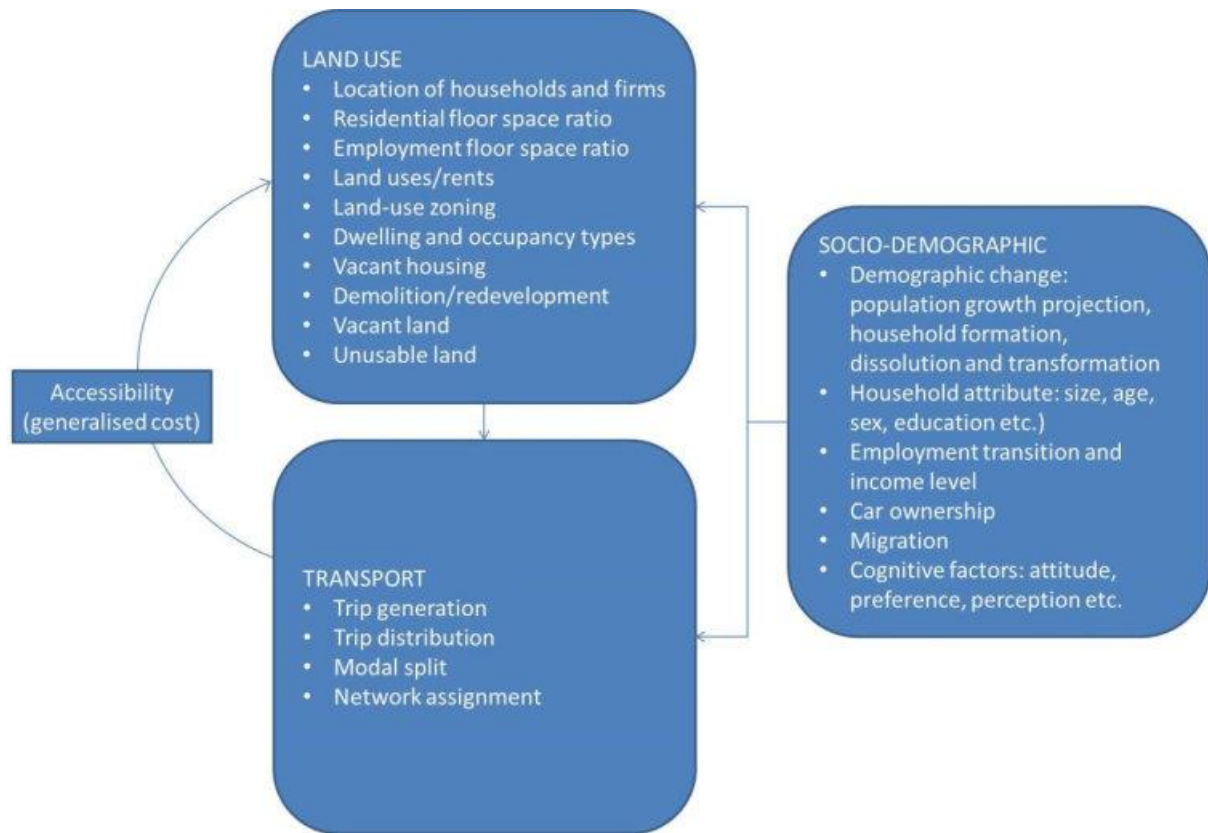


Figure 2-2 Generalized structure of an operational LUTI model

Source: Acheampong and Silva, 2015

The land use model usually includes information on the urban land market such as employment space ratio, land values, dwelling and occupancy types, housing vacancy etc. Most of the existing models have detailed urban land use and housing market sub-models. The socio-demographic model contains important socioeconomic variables that mediate household location choice and travel behaviour. Different model platforms capture varying levels of detail in terms of socio-demographic factors and processes. Most LUTI models divide households or population into segments of similar socioeconomic groups. For example, MUSSA-ESTRAUS (Martinez, 1996) and RAMBLAS (Veldhuisen, Timmermans, & Kapoen, 2000) are based on 13, and 24 different population segments respectively. Some models are able to capture the dynamics of the socio-demographic change. For example, DELTA-START (Simmonds, 1999) and UrbanSim (Waddell, 2002) has detailed demographic transition model that simulates the dynamics of household

formation, dissolutions, and transformations as well as employment transition model that simulates the creation and removal of jobs.

The transport model of most of the existing operational LUTI models, particularly the spatial interaction-based and utility-based ones, adopt the four-step approach as described earlier. As shown in Figure 2.2 above, the land use model is dynamically coupled with or, for some models, integrated within the transport model containing a network assignment module. The outputs from network assignment module are generalised transport costs, manifested by congested networks, travel times and distance, and are fed into the land use model.

In terms of modelling approaches,

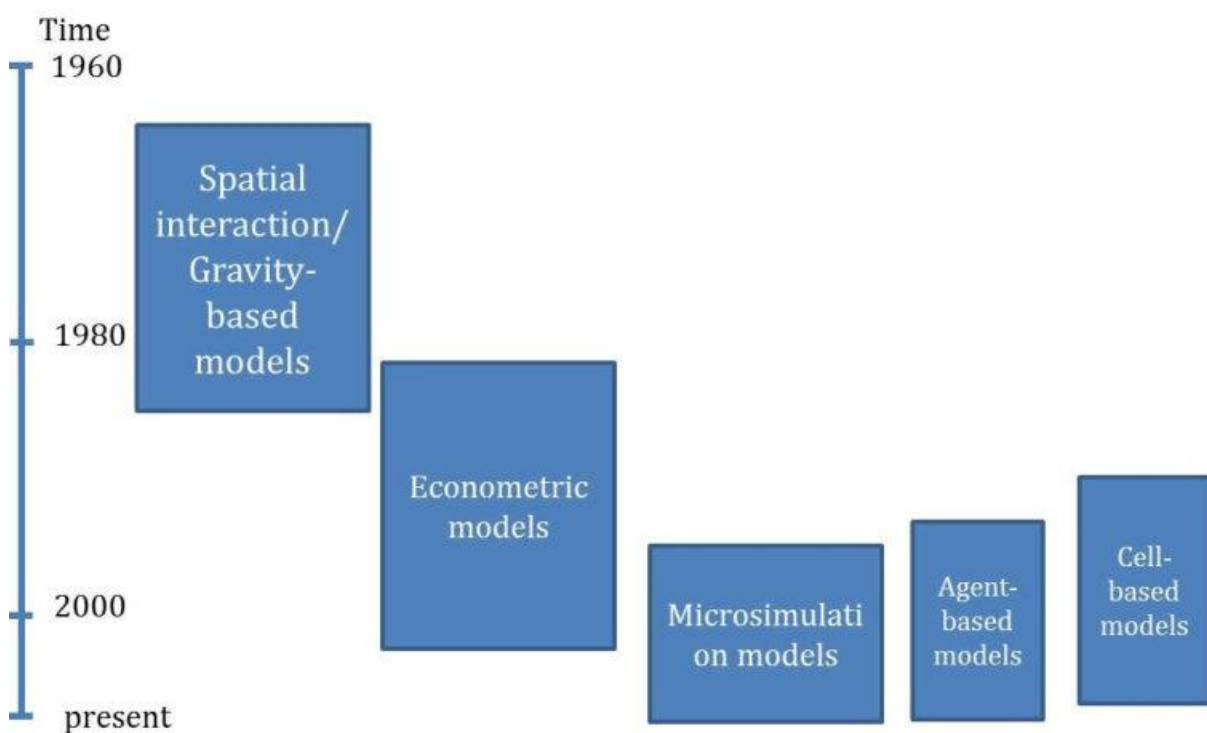


Figure 2-3 describes an approximate timeline for adoption of various modelling approaches within transport and land use research.



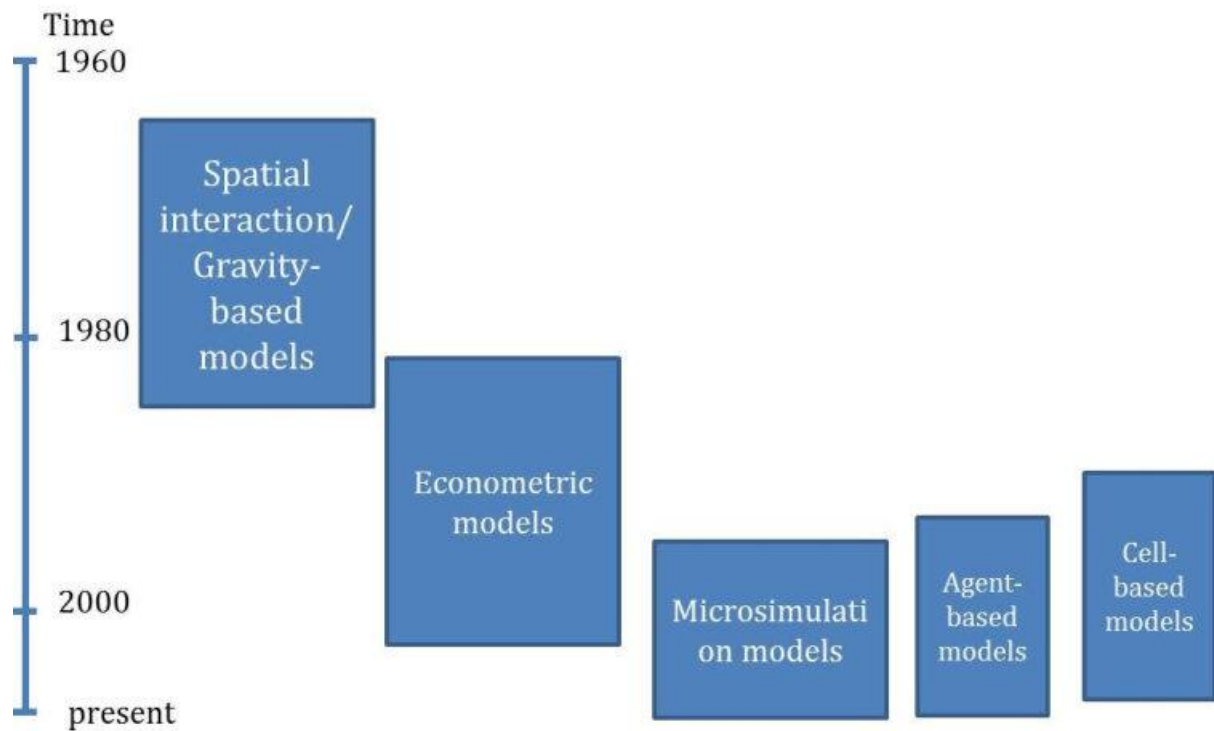


Figure 2-3 Chronological development of LUTI models

Source: Iacono, Levinson, & El-Geneidy, 2008

The transition from one approach to the other does not necessarily mean a complete abandonment of the previous approaches. Instead, new modelling approaches learn lessons from the past and adopt emerging theoretical and empirical insights aiming to address the limitations of their predecessors. Early LUTI models were aggregate spatial interaction models employing the gravity analogy supported by the theory of entropy maximisation (Wilson, 1970) to describe the behaviour of firms and households in space. Very few examples of this type of modelling framework remain. The shortcomings of these models were numerous. For example, most were static equilibrium models incapable of capturing the dynamics of urban systems; none of the models actually represented land markets with explicit prices; zones were highly aggregate and lacked spatial detail, and the models were inadequately supported by theory. Inadequate theory may have also been a reason that many of the models forecasted so poorly. Lee (1973) characterized mistakes of the first generation of models as being too complicated, overly aggregate, data hungry, wrongheaded, extraordinarily complicated, too mechanical, and expensive. Many of these criticisms informed the next generation of models, which took guidance from developments in econometric modelling based on random utility theory.

The work by McFadden (see Domencich and McFadden, 1975) and Williams (1977) gives the theoretical basis for modelling the spatial economy. As a result, economic evaluation is made possible through the use of random utility theory and advancements in discrete choice modelling.

LUTI models that follow econometric approach can be categorised as two types of models: regional economic models and land market models. In both models, transport flows are predicted by the core engine – a regional economic model realised by input-output analysis or a land market model of residential and commercial real estate. Several of the LUTI models with econometric approach continue to be used today since utility theory and theories of decision making under uncertainty are operationalized using mathematical formulations of mainly logistic regression models that vary in their complexity but are reasonably parsimonious and tractable (Iacono, Levinson, & El-Geneidy, 2008).

In the 1990s, with improvements in computational technology and advances in modelling theory and methodology, the microsimulation approach increasingly came into fashion, including activity-based models for travel, cell-based models for land use, as well as multi-agent models for urban simulation (Wegener, 2004). More recently, some researchers have begun to develop comprehensive urban microsimulation models that fully reflect the dynamics of changes in the population and the urban environment within which they make choices.

## **2.5 A case study of land use and transport model software MEPLAN**

Of the main operational policy-oriented LUTI models, MEPLAN represents one of the most extensively developed, in terms of infrastructure planning assessments and land use/transport interaction mechanisms (Echenique, 2004). The development of MEPLAN first drew inspirations from the efforts to spatialize Leontief's intersectoral Input-Output approach (Leontief, 1951, 1967). This approach provides a general framework to integrate intersectoral industrial activities, which was served as exogenous inputs of the urban dynamics in earlier Lowry-based models. Bringing the entropy theory and its logit forms, the approach extends into spatial disaggregation with origin-destination production and attraction-constrained coefficients. It has been used for planning researches in various cities (London, Maples, Helsinki, Tokyo, Cape Town and Santiago, Beijing), regions (the South East of England, the East Midlands region of England, the Basque region of Spain, Bolzano in Italy and the Central region of Chile), nations (Great

Britain, Colombia, Sweden, Chile and Argentina), and a strategic passenger and freight model of the European Union and surrounding countries.

### 2.5.1 Overall structure and operation of the model

The theoretical structure of the MEPLAN model is represented by three interrelated modules: the land use module (LUS), the land Use/transport Interface Module (FRED) and the transport module (TAS).

These modules operate on a time period by time period basis. This means the transport module is influenced by existing infrastructure and spatial patterns of activities; while the land-use module is affected by both the previous and current transport accessibilities.

Figure 2-4 shows MEPLAN's running through time.

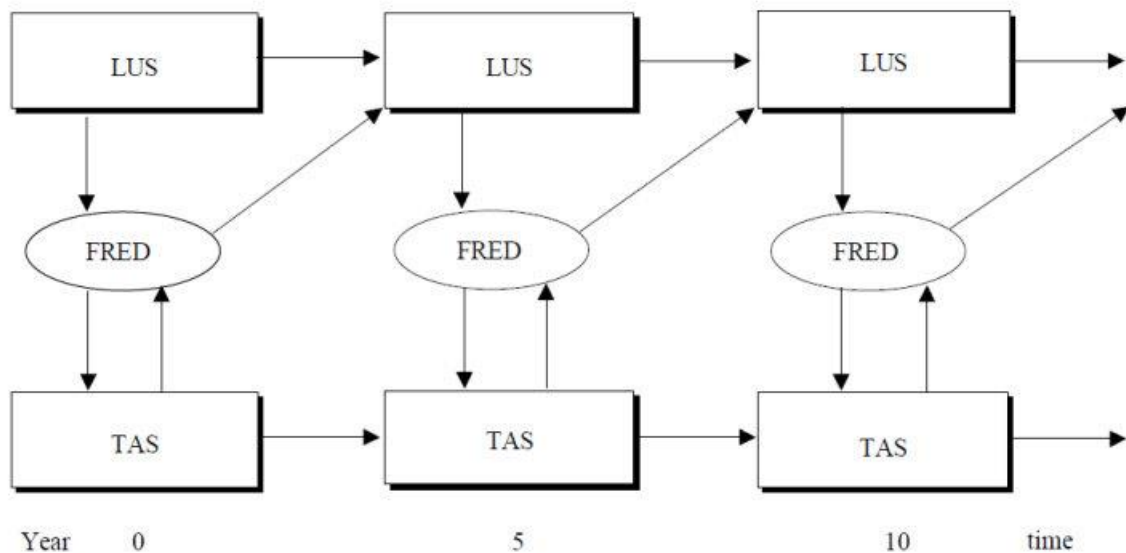


Figure 2-4 Dynamic operation of the model

Figure 2-5 illustrates the typical structure and operation of a MEPLAN model and next section describes the role of the individual modules.

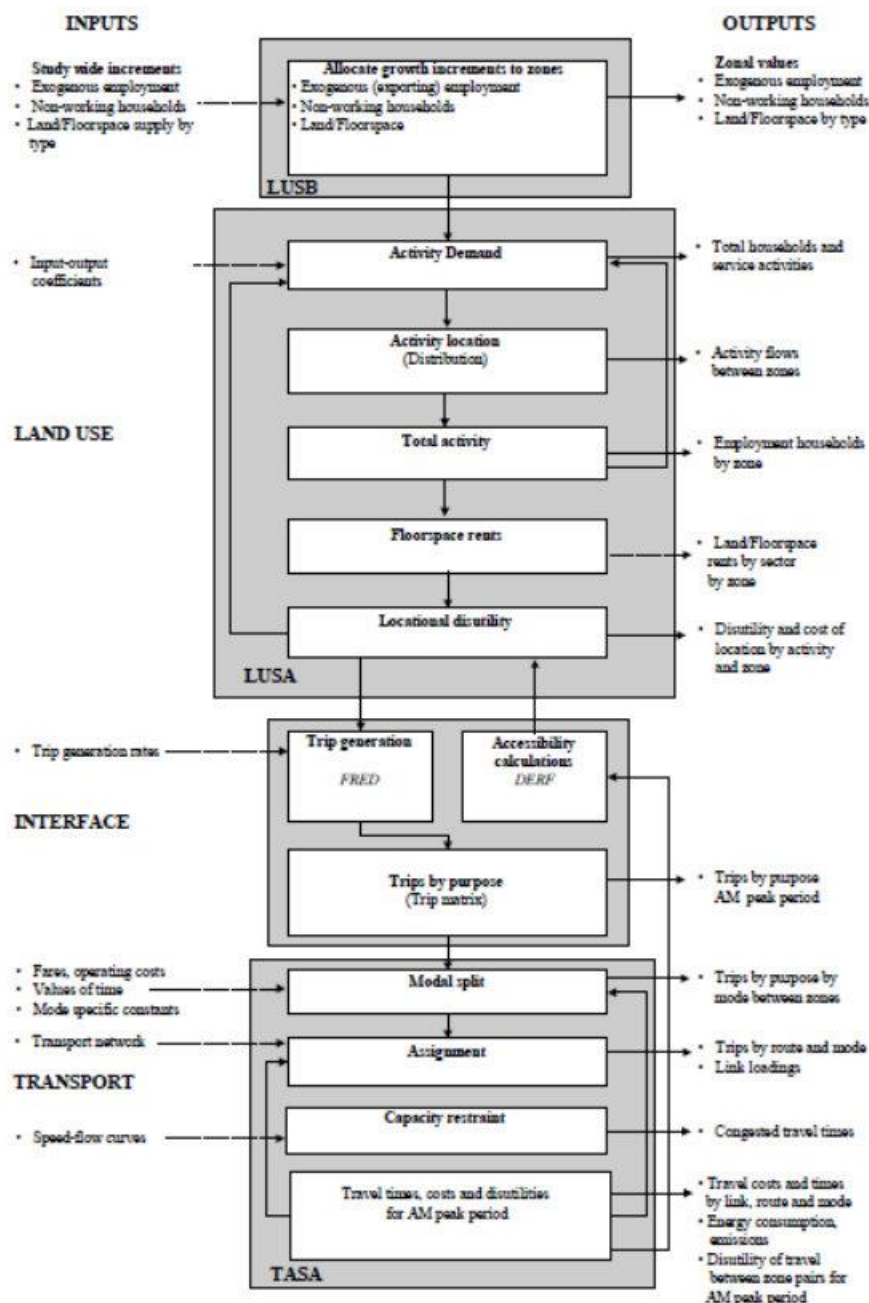


Figure 2-5 Typical structure and operation of a MEPLAN model

### 2.5.2 The land use module (LUS)

This module models the spatial location of activities such as employment and population and produces trades between zones. Planning information represented by groups is referred to as factors. These factors include elements such as population, employed persons, land/floorspace, goods vehicle travel, other travel and other goods and services. With the definitions of various factors, the land use submodel LUSA represents the spatial-economic linkages between activities or land uses.

LUSA incorporates the following:

(i) An input-output model. This is based upon the concept that the production of some economic activity (an output) consumes a range of other types of economic activities (inputs). These inputs, in turn, consume further inputs and so on during the process of production. To drive the input-output mechanism, MEPLAN relies upon the separation of employment into two types, an exogenous and endogenous employment. Exogenous employment is used to represent economic sectors producing primarily export demanded by markets outside the study area and the location of this employment is not determined by the need for access to a local market.

(ii) An elastic consumption model. This enables the consumption of goods, services and space to vary with prices and income. For example, households may consume more if incomes rise and businesses may use office space and labour more intensively as prices rise.

(iii) A spatial choice model. This predicts where factors will locate, and by extension the pattern of trades between zones. The spatial allocation process essentially takes as fixed the demand for a factor in a consumption zone, and distributes the satisfaction of this demand among the sources of supply in the production zones. The allocation process is based upon the "cost of living" in the zone, the disutility of travelling between the production and consumption zones, the availability of land/floorspace in the zone and an extra disutility (or attraction factor) term.

The land use sub-model is moved forward through time using a second sub-model, LUSB. This uses incremental models to allocate any zone specific or study wide land or changes in floorspace and exogenous employment. In the case of floorspace, LUSB allocates the increment to zones in proportion to zonal "attractiveness". This typically includes measures of zonal capacity for development, rent per unit land/floorspace for residential uses, and previous amount of land/floorspace and rental levels for retail and business uses. In the case of exogenous employment, allocation is also based on zonal attractiveness with the employment attractiveness term typically including previous employment and the cost of location (labour plus rents) in the zone.

### **2.5.3 The land use/transport interface module (FRED)**

This converts land use trade matrices into transport flow matrices by socio-economic group and trip purpose or transport disutility into trade disutility.

#### **2.5.4 The Transport module (TAS)**

The main module of the transport sub-model, TASA, is comparable to the latter stages of a conventional four-stage transport model in that it carries out modal split, route assignment and capacity restraint. The trips are assigned into travel modes by logit models onto the transport networks. The assignment of traffic makes use of Dial's probabilistic multipath assignment method (1971), which takes account of the costs and congested travel time over all forward feasible paths towards each origin. The resultant transport disutility are then passed on via the interface module to act as an influence on land use location in the next time period.

#### **2.6 Case study 2: SIMULACRA**

SIMULACRA is also prefaced by an input-output model which drives employment growth (Batty, et al., 2013). SIMULACRA is a series of fast, visually accessible, cross-sectional urban models for large metropolitan areas that enable the rapid testing of many different scenarios pertaining, both, short-term and long-term urban futures. The models are multi-sector, dealing with residential, services, and employment location. They are highly disaggregate, and subject to constraints on land use densities and transport capacities. Several versions of the model now exist, however, in here, a brief outline is presented. Figure 2-6 shows a basic outline of the cross-sectional structures and many-sector models that the framework dealt with.

This modelling effort began in 2007 with the construction of a residential location model for the Greater London Authority (GLA) region which was part of an integrated assessment of climate change, largely sea-level rise over the next 100 years. Later, the model extended to cover a much larger region including a region from Reading in the west to Southend in the east and from Luton in the north to Gatwick-Crawley in the south. This is what is referred to as the Outer Metropolitan Area which has a population of about 14 million in comparison with the GLA area that has around 8 million.

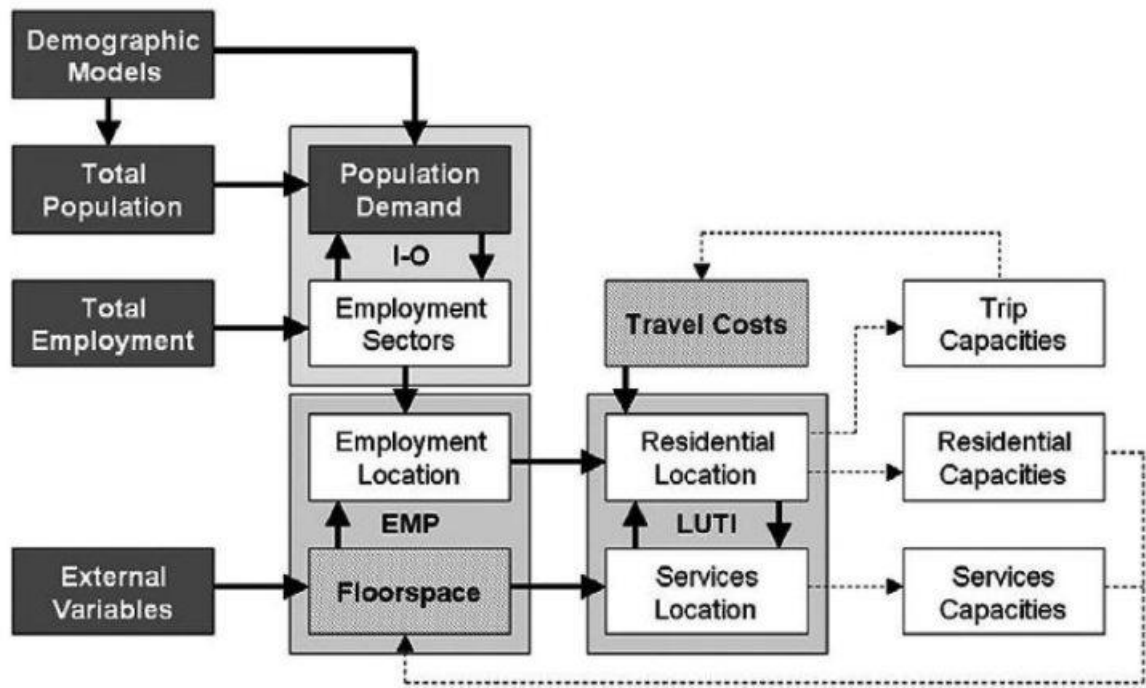


Figure 2-6 The SIMULACRA model structure.

Aggregate external totals are coloured dark grey; external zonal variables are coloured light grey; predicted variables are coloured white.

Source: Batty et al., 2013

The model links activity types through spatial interactions: the journey home to work defined by trips  $T_{ij}$  linking population to employment, trips  $S_{ij}$  from residential areas to services centers (shopping, health, education, and leisure), and through implicit industrial linkages measured as accessibilities to employment and to commercial activities. A formal description of these activities and the way they can be disaggregated and extensions to such classifications are shown in Figure 2-7 and Table 2-1.

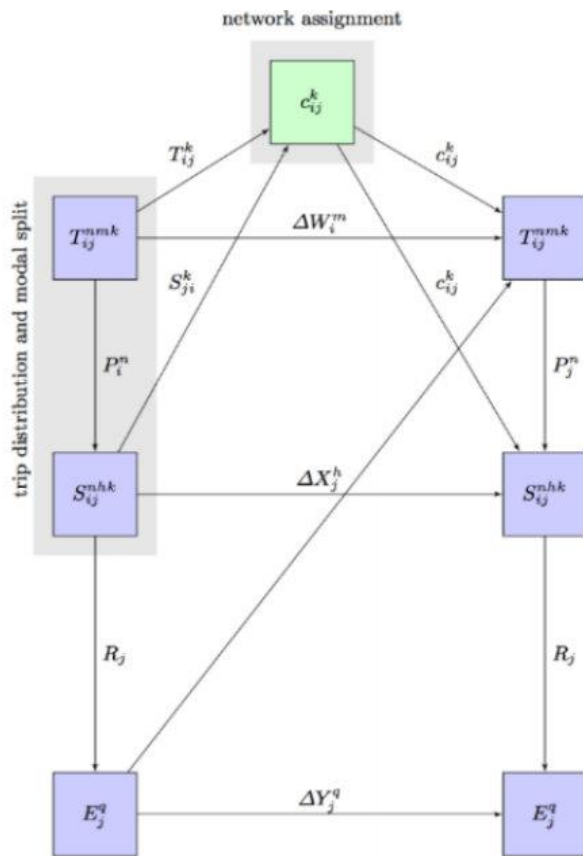


Figure 2-7 SIMULACRA framework overall sequence of sub-models

Source: Batty et al., 2013

Variable	Description
T <sub>ij</sub>	Trip from home to work
S <sub>ij</sub>	Trips from home to services
c <sub>ij</sub>	Generalised travel cost
P <sub>i</sub>	Population
R <sub>j</sub>	Service employment
E <sub>j</sub>	Total employment
W <sub>i</sub>	Residential floorspace
X <sub>j</sub>	Service floorspace
Y <sub>j</sub>	Commercial office floorspace
n	Type of person
m	Type of residence
h	Type of service centre
q	Type of employment sector
k	Type of mode of transport

Table 2-1 Variables used in SIMULACRA



## 2.7 Critical summary

Conventional four step model do not generally tend to model trips outside AM peak period, or even if they did, the results are rarely well checked. Activity-based travel demand models explicitly treat spatial and temporal interdependencies in activity and travel choices and therefore discretionary travels occurring outside the AM peak period are inherently modelled. Also, this type of model views travel within the context of overall daily time-use and emphasis on household level decision making and interaction among household members. So, it is suitable for modelling the time-of-day choices which help assess travel demand management strategies such as congestion charging. However, such models although lends itself well to realistic policy evaluations, they do not consider the wider economic and land use factors that may have an overarching effect on the congestion level. The impacts of wider economic and land use factors are especially an urgent matter for urban hubs where the business, social and leisure activities aggregate and crowding and congestion occurs outside the AM peak period. As the overcrowding and congestion translate into high property and goods prices, lower productivity, inefficiency and social exclusion may ensue.

As reviewed earlier, LUTI model provides a framework to model the interaction between the land use and transport that allows for forecasting medium to long term travel demand changes. It can potentially address the deficiency of the traditional four step model and activity-based model that the land uses are seen as fixed. While the early LUTI models were not in use due to several reasons described above the models based on microsimulation have too high data requirement and long running time and therefore has rarely been used in practice. Moreover, the stochastic variation in model results between different simulations runs of different random number seeds means that model results may be presented with illusionary precision (Wegener, 2011). Several of the LUTI models with econometric approach such as MEPLAN continue to be used today grounds in robust economic and behaviour theories while the mathematical formulations are tractable. However, such types of LUTI models tend to focus on non-discretionary activities such as rush-hour commuting. The existing models are not well adapted to addressing non-discretionary social and leisure activities such as during afternoon and evening periods. In MEPLAN, the personal trips for purposes other than commuting and employer's business are currently modelled in a relatively simple way. Also, no differentiation has been made regarding different leisure activities, in terms of trip attractions. Similarly,

SIMULACRA does not directly model shopping and leisure trips in its spatial input-output structure. Instead, it applies a conversion factor to derive shopping trips based on the estimated retail jobs at a rather crude aggregate level. The model although applies in Greater London Area, it does not model night time activities in London where the night economy has become an essential part of the city. Notwithstanding the above, the model's design to allow quick and agile scenario tests is unique in the model of this kind.

To sum up, the principle of activity based modelling provides a way to generate discretionary travel demand such as night market visits. MEPLAN has been developed based on random utility theory which reflects individual's travel behaviour and the econometric framework provides the opportunity to estimate travel demand from potentially a wide range of land use activities, which is increasingly supported by emerging social media sources. The simple and direct SIMULACRA style of scenario tests with simple, incremental input changes enables many different alternative futures to be assessed rapidly, particularly for strategic assessments of distinct land use and transport scenarios.

## **Chapter 3 METHODOLOGY**

### **3.1 Methodological framework**

The purpose of this research is to establish a new methodological framework for modelling traffic in all time periods in a large city region for practical policy applications. This means that the method will draw upon all three main transport modelling traditions and then extend them in a way that can be well supported by currently available data sources. The methodological framework will thus combine three intellectual traditions of transport demand and supply modelling: first, it will adopt the mode choice and traffic assignment modules from the four step transport model tradition because this is what can be supported by current data sources in model calibration and validation; second, for generating discretionary travel demand such as residents' and tourists' night market visits, it will adopt the principles of activity based modelling, where we establish new methods that are supported by emerging social media sources; thirdly, for forecasting medium to long term travel demand changes, it adopts a land use/transport interaction modelling framework; more specifically it sets up the core travel demand forecasting capabilities in the MEPLAN tradition, and adopts the quick and agile SIMULACRA style of scenario tests with simple, incremental input changes. The modelling framework can thus become capable of generating medium to long term travel demand shifts and translate them into modal flows and traffic assignments across all the peak and non-peak time periods. Such model outputs can then be used through pairwise scenario comparisons of distinct land use and transport policy packages and provide insights into the efficacy of infrastructure investment as well as the effectiveness of travel demand management.

Figure 3-1 illustrates the core model of the methodological framework, which builds on the land use/transport interaction models. This core model is established for each modelled year whether in the base year (for calibration, verification and validation) or the forecast years.

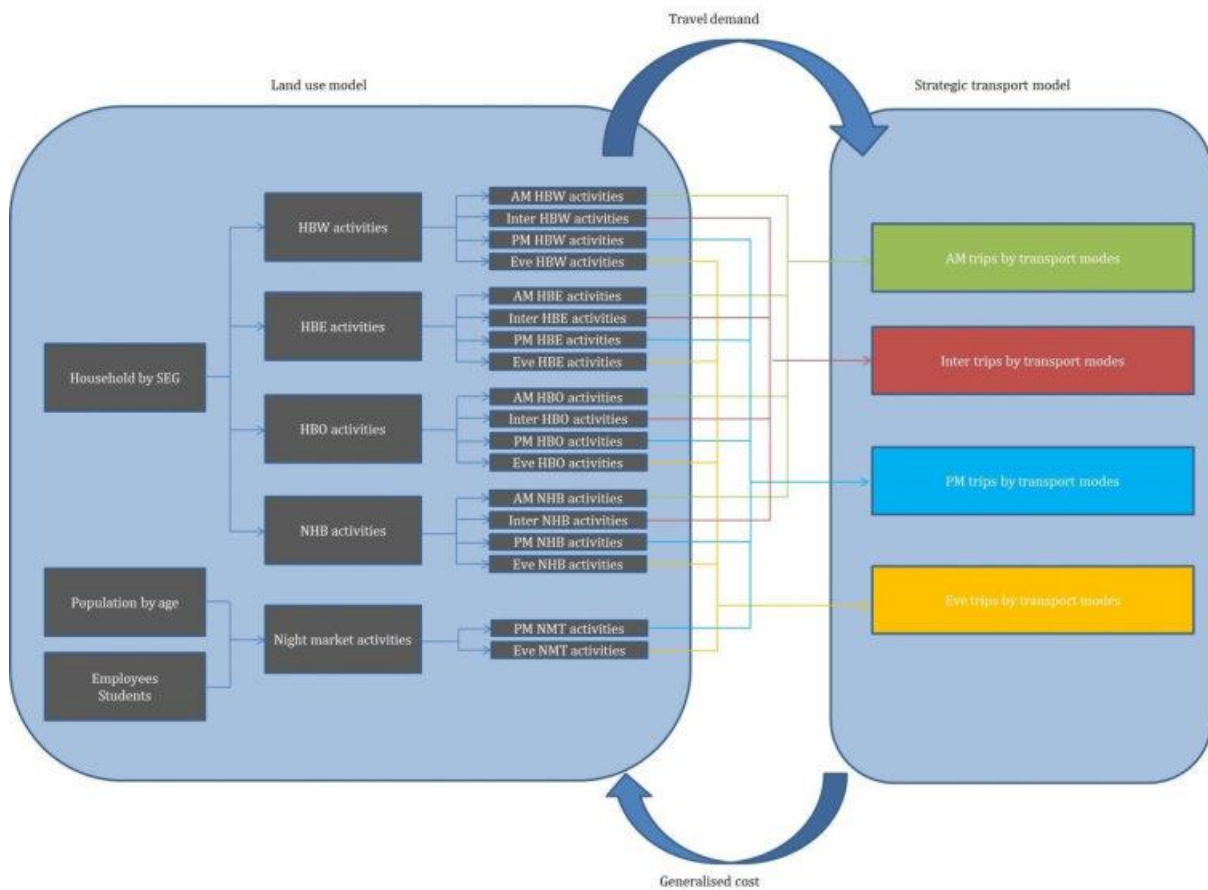


Figure 3-1 Proposed model structure

The information flow within the core model can be broadly described in terms of four interlinked simulation procedures, the first two of which are considered land use and the remaining two transport:

(a) Activity generation: Households of different socio-economic groups in the consumption zones are used to generate demand for education, shopping/personal business, leisure, and other services, which are provided in the production zones. Similarly, demand for night market activities, located in the production zones such as the night market clusters, are estimated based on the presence of residents and tourists.

(b) Spatial distribution of the travel demand: Logit-based discrete choice models are applied to distribute the demand between each pair of production and consumption zones.

(c) Mode Split: The journeys are attributed to modes of transport that are available between each pair of origin and destination zones, according to the modal choice behaviour of each socio-economic group, for each travel purpose, for each time period.

(d) Link Assignment: The journeys on each mode are then assigned to road and rail (including metro) networks using a stochastic user equilibrium algorithm, which can either incorporate road and rail service capacity restraints, be assigned free of capacity restraints or be assigned based on certain assumptions of traffic speeds (such as maintaining the constancy of congestion as observed in the base year) in order to explore future utilisation of the transport network and services under alternative planning scenarios.

Whilst travel demand information is generated and fed top-down from (a) to (d), the travel costs, times and time based generalised costs are transmitted bottom-up from (d) to (a). This allows an extensive interaction between land use and transport. In the above, Steps (a) and (b) are regarded as the land use module, which replaces the trip generation and trip distribution steps of a conventional four-step model. Steps (c) and (d) are thus the main contents of the strategic transport module.

### **3.2 Land use**

For the purposes of the model, activities will be split into two broad groups:

(a) conventional activities that will translate into trips including Home Based Work (HBW), Home Based Education (HBE), Home Based Other (HBO) and Non Home-Based (NHB)

(b) night market activities that will translate into trips to night market clusters, which are rarely covered by existing transport or land use/transport models.

Within the model, each sector is composed of a number of land use factors which represent various activities of production and consumption and respective producers and consumers.

### 3.2.1 Conventional activities

#### 3.2.1.1 Conventional activity generation

The demand for conventional activities is generated based on households, which represent the consumers in the model. The demand can be expressed as follows:

$$Y_j^{mn} = HH_j^m * t_{mn} \quad [\text{Equation 3.1}]$$

Where

$Y_j^{mn}$  is the total demand for factor n by household type m in zone j

$HH_j^m$  represents the number of household type m in zone j

$t_{mn}$  represents the demand coefficient for factor n by household type m

#### 3.2.1.2 Spatial interaction process of conventional activities

The households' demands for industrial and service factors are transportable (trade) and the model estimates the location of production of these factors. The trade from zone  $i$  to zone  $j$  is equal to the total demand for a factor in zone  $j$  multiplied by the probability of it being produced in zone  $i$ . A logit-based discrete choice model is applied to simulate the spatial distribution for these trades:

$$T_{ij}^{mn} = Y_j^{mn} \frac{S_i^n e^{-\lambda^{mn}(d_{ij}^{mn})}}{\sum_i S_i^n e^{-\lambda^{mn}(d_{ij}^{mn})}} \quad [\text{Equation 3.2}]$$

where

$T_{ij}^{mn}$  is the flow of factor n (in production zone  $i$ ) demanded by household type m in consumption zone  $j$

$Y_j^{mn}$  is the total demand for factor n by household type m in zone  $j$

$S_i^n$  is a factor influencing the attractiveness of factor n in zone  $i$

$d_{ij}^{mn}$  is the disutility of transport (generalised cost) between zone  $i$  and  $j$  for factor n demanded by household type m

$\lambda^{mn}$  is a positive concentration parameter which specifies the choice behavior of factor n by household type m when faced with the disutility

### Attractiveness of conventional activities

The term influencing the attractiveness of factor can be expressed as follows (CECI, 2009):

$$S_i^n = Constant^n + a^n E1_i + b^n E2_i + C^n P_i \quad [\text{Equation 3.3}]$$

Where

$S_i^n$  is a factor influencing the attractiveness of factor n in zone i

$E1_i$  is number of employees in a secondary industry in zone i

$E2_i$  is number of employees in a tertiary industry in zone i

$P_i$  is the number of students in zone i

$Constant^n$ ,  $a^n$ ,  $b^n$  and  $c^n$  is the parameters for different types of factor n

### **3.2.2 Night market activities**

Since the night markets have recently become a major tourist attraction in cities around the world, it is worth factoring in the tourists when it comes to simulating activities occurring at night. Therefore, the night market activities consist of those of residents and those of tourists.

#### **3.2.2.1 Night market activity generation by residents**

According to the literature (Yen, 2011; Lee et al., 2015), it is found that night markets visitors differ greatly by age group. Therefore, the demand for night market activities is generated based on people of different age groups in the model.

$$Y_j^a = Pop_j^a * t_a \quad [\text{Equation 3.4}]$$

Where

$Y_j^a$  is the total demand for services of the night market activities by residents of age group a in zone j

$Pop_j^a$  represents the number of population of age group a in zone j

$t_a$  represents the demand coefficient for service of night market activities by age group a

### Home-based demand

In fact, trips to night market activities are made by people who travel from home and also by people who travel from workplaces or schools. Therefore, the demand generated by the above equation will be expanded further to treat these two types of demands differently. The equations below illustrate the estimation of demand for home-based and non-home based night market activities.

$$YH_j^a = Y_j^a * p_a = Pop_j^a * t_a * p_a = Pop_j^a * th_a \quad [\text{Equation 3.5}]$$

Where

$YH_j^a$  is the total demand for night market activity by age group  $a$  from homes in zone  $j$

$p_a$  is the percentage of people of age group  $a$  seeking night market activity that travel from home

$th_a$  represents the demand coefficient for night market activity by age group  $a$  travelling from home

$Y_j^a$ ,  $Pop_j^a$  and  $t_a$  represent the same as in Equation 3.4

### Non home-based demand

Those people going to the night markets from schools are most likely to be people aged under 24 while those travelling from workplaces are aged between 25 and 59. Therefore, demand made by people from workplaces or schools can be expressed as follows:

$$\begin{aligned} Y_j^{student} &= YNH_j^{0-14} + YNH_j^{15-19} + YNH_j^{20-24} \\ &= YH_j^{0-14}(1 - p_{0-14}) + YH_j^{15-19}(1 - p_{15-19}) + YH_j^{20-24}(1 - p_{20-24}) \end{aligned} \quad [\text{Equation 3.6}]$$

$$\begin{aligned} Y_j^{employed\ worker} &= YNH_j^{25-29} + YNH_j^{30-34} + YNH_j^{35-39} + YNH_j^{40-59} = \\ &= YH_j^{25-29}(1 - p_{25-29}) + YH_j^{30-34}(1 - p_{30-34}) + YH_j^{35-39}(1 - p_{35-39}) + YH_j^{40-59}(1 - p_{40-59}) \end{aligned} \quad [\text{Equation 3.7}]$$

Where



$Y_j^{student}$  is the total demand for night market activity by students at schools in zone  $j$

$Y_j^{employed worker}$  is the total demand for night market activity by employees at workplaces in zone  $j$

$YNH_j^{0-14}$  to  $YNH_j^{40-59}$  are the demand for night market activity by each age group at either schools or workplaces in zone  $j$

$p_{0-14}$  to  $p_{40-59}$  are the percentage of people by each age group seeking night market activity that travel from home

### ***3.2.2.2 Spatial interaction process of night market activities by residents***

#### **Home-based**

Similarly to the spatial distribution for conventional activities in 3.2.1.2, a discrete choice equation is used to spatially distribute the night market activities:

$$T_{ij}^a = Y_j^a \frac{S_i e^{-\lambda^a (d_{ij}^a)}}{\sum_i S_i e^{-\lambda^a (d_{ij}^a)}} \quad [\text{Equation 3.8}]$$

where

$T_{ij}^a$  is the trade factor of night market services (in production zone  $i$ ) demanded by age group  $a$  in consumption zone  $j$

$Y_j^a$  is the total demand for night market services by residents of age group  $a$  in zone  $j$

$S_i$  is a factor influencing the attractiveness of night market in zone  $i$

$d_{ij}^a$  is the disutility of transport (generalised cost) between zone  $i$  and  $j$  for age group  $a$  living in zone  $j$

$\lambda^a$  is a positive concentration parameter which specifies the choice behaviour of age group  $a$  when faced with the disutility

And the similar formulation can be applied to the spatial interaction for non home-based demand.

### Non home-based

$$T_{ij}^{student} = Y_j^{student} \frac{S_i e^{-\lambda^{student}(d_{ij}^{student})}}{\sum_i S_i e^{-\lambda^{student}(d_{ij}^{student})}} \quad [\text{Equation 3.9}]$$

$$T_{ij}^{employed worker} = Y_j^{employed worker} \frac{S_i e^{-\lambda^{employed worker}(d_{ij}^{employed worker})}}{\sum_i S_i e^{-\lambda^{employed worker}(d_{ij}^{employed worker})}} \quad [\text{Equation 3.10}]$$

where

$T_{ij}^{student}$  or  $T_{ij}^{employed worker}$  is the trade factor of night market services (in production zone  $i$ ) demanded by students or by employed workers in zone  $j$

$Y_j^{student}$  or  $Y_j^{employed worker}$  is the total demand for of night market services by students studying or by employed workers working in zone  $j$

$S_i$  is a factor influencing the attractiveness of night market activities in zone  $i$

$d_{ij}^{student}$  or  $d_{ij}^{employed worker}$  is the disutility of transport (generalised cost) between zone  $i$  and  $j$  for students studying or employed workers working in zone  $j$

$\lambda^{student}$  or  $\lambda^{employed worker}$  is a positive concentration parameter which specifies the choice behaviour of students or employed workers when faced with the disutility

### Attractiveness of night market for residents

This section discusses how the factor influencing the attractiveness of night market activities in a zone  $i$  was determined for the model. The attractiveness term in the models has been a major difficulty that has hampered the modelling of discretionary activities such as travel to the night markets. However, the new social media review sites may provide a new source of information.

With the advance in internet technology, social media platforms have become new sources of user-generated urban datasets. However, the excessive amount and the scattering of online reviews sometimes make it cumbersome for consumers to obtain the most relevant information. Therefore, some online review websites such as TripAdvisor, Yelp, Foursquare and Dianping have emerged to provide useful repositories of quality reviews to consumers. The review system of these websites contains specific information

about the locations of points of interest and sometimes some demographic information about reviewers. These datasets provide an opportunity to inform land use models in a much higher resolution than through the use of conventional datasets. For example, the use of crowd sourced data can help identify up and coming locations across the city and emerging new centres of activity by monitoring the spatial distribution of this activity over time. The popularity of each commercial centre within a city can be deduced by using ratings and reviews left by reviewers. All this information is not easily captured by the conventional survey method.

These websites operate on a peer review system and employ quality control teams to keep the review quality under control. The reviews or the ratings can still be misleading even with the quality assurance mechanism in place. However, the use of social media data for this research is to identify the relative attractiveness of a zone as opposed to the absolute attractiveness of an individual shop. Thus, the total number of comments left within a zone is of concern here because the total number of comments left can reflect the footfall in a shopping area which in turn can be translated into the relative attractiveness of a zone.

Thus,  $S_i$  in Equation 3.10 can be expressed as:

$$S_i = C_i \quad \text{[Equation 3.11]}$$

Where

$S_i$  is a factor influencing the attractiveness of night market in zone  $i$  for residents

$C_i$  represents number of comments on shops in zone  $i$

### **3.2.2.3 Night market activities generation by tourists**

Similarly to the activities generation by residents, the generation by tourists can be expressed with the following equation:

$$Yt_j = Pop_j^t * tt \quad \text{[Equation 3.12]}$$

Where

$Yt_j$  is the total demand for night market activities by tourists in zone  $j$

$Popt_j$  represents the number of tourists staying in zone  $j$

$tt$  represents the demand coefficient for night market activities by tourists

Number of tourists and where they stay can be difficult to capture with official records so this research establishes a method of estimating number of overnight tourists and the location of the stay by making use of official records as well as emerging data available online. The official records relating to overnight tourists are the statistics on accommodation business. However, the business landscape is constantly changing so it is hard to keep track of all the business in the sector. Some websites provide travel-related comments are of particular interest for this research because they usually contain the information on accommodation establishments in the cities the websites have operated in and provide up-to-date lists of business. This type of data can be thought of as a supplement to the official records as many independently owned and operated hotels or hostels cannot be found on the official records. Besides, recent years have seen the online platforms based on sharing economy idea providing peer-to-peer accommodation services become increasingly popular and travellers around the world have more options for their accommodating arrangement. Therefore, the number of tourists using this type of online platform needs to be included in the estimation. Also, it is worth noting that people sometimes stay with friends and family when they travel and this is hard to be traced so this research also includes estimate of this type of tourists with data from a local survey. The following sections describe the methodology of overnight tourists estimation by using (1) official statistics, (2) travel-related review websites, (3) peer-to-peer accommodation online platform and (4) local survey. As night markets are places to eat and socialise in the evenings, it can be assumed that tourist trips to the night markets will originate from their place of stay rather than from places of day-time activity.

### **1. Estimation with official statistics:**

We estimate the number of guests in each type of accommodation establishment every night by allocating the total number of guests per day of each type to zones based on the number of rooms of the corresponding hotel type in each zone. The function can be expressed as follows:

$$g_j^a = G^a \frac{r_j^a}{\sum_j r_j^a} \quad [\text{Equation 3.13}]$$

Where

$g_j^a$  represents the daily number of guests staying in accommodation establishment type a in zone j

$G^a$  represents total number of guests staying in accommodation establishment type a each day

$r_j^a$  represents total number of rooms of accommodation establishment type a in zone j

## 2. Estimation with data from travel-related review websites:

Most of the travel-related commenting website contains information on the name, types and location of each listed accommodation establishment.

However this online information, although is detailed in some aspect, is limited in that it does not reveal much about the statistics such as number of guests, number of rooms or beds and occupancy rate which are helpful to estimate the number of guests per night for each accommodation establishment at zonal level. Thus, data from other sources is required to complement this type of online information. For many official statistics, yearly data, or even more temporally disaggregated data, on number of guests arriving at accommodation establishments and number of accommodation establishment for each type is collected. This information can be used to derive the average daily number of guests arriving in each accommodation establishment by type. Therefore, we can estimate at zonal level the number of guests in each type of accommodation establishment every night. The function is expressed as follows:

$$g_j^a = E_j^a * g^a \quad [\text{Equation 3.14}]$$

Where

$g_j^a$  represents the daily number of guests staying in accommodation establishment type a in zone j

$E_j^a$  represents number of accommodation establishment type a in zone j

$g^a$  represents the estimated number of guests per night by accommodation establishment type a

### 3. Estimation with data from peer-to-peer rental platform:

On peer-to-peer rental platform, each listing specifies how many guests are allowed by the host for each night. Therefore, the approximation for estimating the number of guests starts by making use of these numbers. The number of guest allowed by each host is shown on the webpages of each listing and easily scraped. Once the number of maximum number of guests is known, an occupancy rate is applied to the summation of maximum number of guests per day. Location wise, each host provides an approximate location of the address of their listings or a map on the webpage showing such location. So each listing can be allocated to each zone based on the latitude and longitude scraped from the website and the total number of guests at zonal level can be obtained.

So the number of people staying at zonal level using peer-to-peer rental platform per day is estimated with:

$$g_j = gm_j * \text{Occupancy rate} \quad [\text{Equation 3.15}]$$

Where

$g_j$  represents the daily number of guests staying in zone  $j$

$gm_j$  represents the number of guests allowed to stay in zone  $j$

### 4. Estimation of people staying with friends and family:

The literature (Lee et al., 2015) shows that apart from tourists staying in accommodation establishments, some people visit the city and stay with friends and family. Therefore, this group of tourists will need to be accounted for in the estimation. The total number of such group can be obtained by applying a ratio of the total number of tourists staying with friends to the number of tourists staying in accommodation establishments estimated from all the previous sources.

$$gf = gh * r \quad [\text{Equation 3.16}]$$

Where

$gf$  represents the estimated daily number of guests staying at friends' and family

$gh$  represents the total number of estimated number of guests staying at other accommodation establishments of all zones estimated with equation 3.13 , 3.14 and 3.15

$r$  is the ratio of number of tourists of staying at friends' and family to number of tourists staying at other accommodation establishments

As with the previous section, the numbers of tourists staying with friends and family are to be allocated to each zone. Since the disaggregated data for each zone is difficult to come by, it is assumed that the number of people of this type of tourists staying in each zone is in proportion to the population size in each zone. Therefore, the number of tourists staying with friends and family in each zone can be calculated with the following equation:

$$gf_j = gf * \frac{p_j}{\sum_j p_j} \quad [\text{Equation 3.17}]$$

Where  $gf_j$  represents the daily number of guests staying at friends' in zone  $j$

$gf$  represents the estimated daily number of guests staying at friends' places

$p_j$  represents the population in zone  $j$

#### **3.2.2.4 Spatial interaction process of night market activities by tourists**

Similarly to the spatial distribution process described earlier, a discrete choice equation is used to spatially distribute the night market activities by tourist:

$$Tt_{ij} = Yt_j \frac{St_i e^{-\lambda t(dt_{ij})}}{\sum_i St_i e^{-\lambda t(dt_{ij})}} \quad [\text{Equation 3.18}]$$

where

$Tt_{ij}$  is the trade factor of night market services (in production zone  $i$ ) demanded by tourists in consumption zone  $j$

$Yt_j$  is the total demand for night market services by tourists staying in zone  $j$

$St_i$  is a factor influencing the attractiveness of night market in zone  $i$  for tourists

$dt_{ij}$  is the disutility of transport (generalised cost) between zone  $i$  and  $j$  for tourists staying in zone  $j$

$\lambda t$  is a positive concentration parameter which specifies the choice behaviour of tourists when faced with the disutility

#### Attractiveness of night market activities for tourists

Similar to the residents, the attractiveness of night market activities for tourists can be derived from social media data and the term  $St_i$  in the equation above is estimated with similar formulation. However, it is believed that tourists also have the tendency to go to shopping areas when they visit a city so the total number of comments left on retail shops in a zone are given equal weighting as comments left on restaurants. Reviews for restaurants and shopping are two categories listed on the review websites which are relevant to night market activities.

The equation takes the comment totals for the restaurants and shops in the area as a proportion of the respective comment totals left for the whole city, and multiplies each by 0.5 for equal weighting, before adding them together into a single score.

$$St_i = 0.5 * \frac{Cr_i}{\sum_j Cr_i} + 0.5 * \frac{Cs_i}{\sum_j Cs_i} \quad [\text{Equation 3.19}]$$

Where

$St_i$  is a factor influencing the attractiveness of night market in zone  $i$  for tourists

$Cr_i$  represents number of comments on restaurants in zone  $i$

$Cs_i$  represents number of comments on shopping areas in zone  $i$

### **3.3 Conversion of production-attraction matrices to OD matrices**

Trade derived from conventional activities for each day estimated above are converted to flows (passenger traffic) for each time period with the following equation.

$$F_{ij}^s = \sum_{mn} (T_{ij}^{mn} \Phi^{mns} \alpha_{ij}^s + T_{ji}^{mn} \Phi^{mns} \omega_{ji}^s) \quad [\text{Equation 3.20}]$$

Where

$F_{ij}^s$  is the flow type  $s$  from zone  $i$  to zone  $j$ , which includes both outwards journeys generated by trade  $T_{ij}^{mn}$  and return journeys generated by trade  $T_{ji}^{mn}$



$T_{ij}^{mn}$  is the flow of factor  $n$  (in production zone  $i$ ) demanded by household type  $m$  in consumption zone  $j$  ;  $T_{ji}^{mn}$  is the flow of factor  $n$  (in production zone  $j$ ) demanded by household type  $m$  in consumption zone  $i$

$\Phi^{mns}$  is the ratio of value of factor  $n$  by household type  $m$  to volume of flow type  $s$ .

$\alpha_{ij}^s$  is the proportion of outwards trips to convert the trips to the time period modelled in the transport model for flow type  $s$

$\omega_{ji}^s$  is the proportion of return trips to convert the trips to the time period modelled in the transport model for flow type  $s$

Similarly, the trade derived from night market activities estimated above are converted to flows for each time period with the following equation.

$$F_{ij}^s = \sum_{mn} (T_{ij}^a \Phi^{as} \alpha_{ij}^s + T_{ji}^a \Phi^{as} \omega_{ji}^s) \quad [\text{Equation 3.21}]$$

$F_{ij}^s$  is the flow type  $s$  from zone  $i$  to zone  $j$ , which includes both outwards journeys generated by trade  $T_{ij}^a$  and (usually a very small amount of) return journeys generated by trade  $T_{ji}^a$

$T_{ij}^a$  is the trade factor of night market services (in production zone  $i$ ) demanded by age group  $a$  in consumption zone  $j$ ;  $T_{ji}^a$  is the trade factor of night market services (in production zone  $j$ ) demanded by age group  $a$  in consumption zone  $i$ ;

$\Phi^{as}$  is the ratio of value of age group  $a$  to volume of flow type  $s$ .

$\alpha_{ij}^s$  is the proportion of outwards trips to convert the trips to the time period modelled in the transport model for flow type  $s$

$\omega_{ji}^s$  is the proportion of return trips to convert the trips to the time period modelled in the transport model for flow type  $s$

### 3.4 Transport Models

As outlined in the previous sections, the approach used in this study focuses on integration of a transport model with a land use model which directly estimates the

demand for transport from the underlying spatial pattern of activities and the linkages between them. Therefore, treating travel demand as a derived demand means that the conventional steps of trip generation and distribution are placed on a sound economic basis within the land use model, leaving only the modal choice and assignment steps to be dealt with within the transport model.

The transport model set up in this study is a strategic multi-modal model and has been set up to use stochastic user equilibrium assignment combined with a hierarchical multinomial logit model for modal split.

### 3.4.1 Modal choice models

The treatment of modal choice is vital in any study which considers both public and private transport. The most commonly used model has a logit form.

$$F_{ijh}^s = F_{ij}^s \frac{e^{-\lambda^s(\phi^s c_{ijh}^s + t_{ijh}^s + p_{jh}^s + \Omega_h^s)}}{\sum_h e^{-\lambda^s(\phi^s c_{ijh}^s + t_{ijh}^s + p_{jh}^s + \Omega_h^s)}} \quad [\text{Equation 3.22}]$$

where:

$F_{ijh}^s$  denotes flow type s from zone i to zone j by mode h

$F_{ij}^s$  is the flow type s from zone i to zone j

$C_k$  denotes out-of-pocket travel cost converted into time units through marginal utility of money  $\phi^s$

$t_{ijh}^s$  denotes travel time

$p_{jh}^s$  denotes destination disutility (such as parking fee) and

$\Omega_h^s$  denotes mode specific constant

$\lambda^s$  is a modal choice parameter which needs to be calibrated

### 3.4.2 Networks and assignment models

The network assignment applies a logit-based, stochastic user equilibrium algorithm (Williams, 1994). In particular, the calibration of the network assignment model starts from congested link speeds from an observed year. Obtaining such congested link speeds

for the entire model study area has been always a great challenge. Typically only fairly small datasets such as from specially commissioned floating car surveys are available, which usually covers only a very small area in the city. The following section will discuss a new method used to obtain congested link speeds suitable for this research.

#### Estimation of congested speeds

Traditionally, in transport modelling, congested speeds could be estimated through, for example, observed traffic flows on each road link from survey data relative to their throughput capacities. And the validation of the model can be done by comparing the modelled speed with the usually limited observations of road speed on key traffic links. This approach usually does not adequately take into account congestion times caused by different traffic queuing behaviour at traffic lights and road merging points. Therefore, the calibration process for the base year model with significant congestion level is costly and difficult to establish. For this research, these issues are compounded by the interest in modelling congested speeds by different time periods covering the all-day travel of the city. To overcome these difficulties, a new approach has been explored to derive congested road speeds for each time period using data obtained from Google Maps Directions through the Google Maps Directions API. The steps are as follows:

1. Pick two nodes as start and end points from the coded network which forms a route composed of a single type of link and being over 2 km in length covering several junctions.
2. Using Google Maps and input the coordinates of these two ends point in the Direction service to see if the given result is a single route which matches the route picked in step 1. If there are multiple results, adjust the route on the map by dragging the end points slightly away from the junction to see if it can yield a single result. If not, go back to step 1 to pick a new pair of points until the result given by Direction service matches the route picked in step 1.
3. Repeat step 1 and step 2 until at least two routes are picked for each broad road type.
4. Estimate the travel time for each route by using the shortest path through Geographic information system (GIS) with the link length and link speed coded in the model.
5. Estimate the travel time for each route with the Google Direction API which produces travel times by the time segment specified. Here, we specify the return of travel times by each hour using a python script. This script makes a request using http through the Google

API with specified departure times. A python script is prepared to get the data with the API.

6. Calculate the ratios between Google travel time (from congested speeds) by each hour obtained in step 5 and network travel time (from coded speed) obtained in step 4. The ratio is served as a part of the conversion rate in the model.

7. Take the average of the ratios by road type and by four time periods.

8. Multiply the ratios by 60 for unit conversion in the model

### **3.4.3 Intrazonal links**

Another task for setting up the transport model is to develop supplementary intra-zonal transport networks. The need for this supplementary network stems from the fact that a transport model cannot assign trips that travel within the zone.

In contrast to detailed road traffic models which are primarily used for relatively short term modelling purposes, a strategic transport model has to consider a wide variety of joint model dimensions, such as land use/transport interaction, multimodal transport systems, more detailed travel demand segmentation and multiple travel time periods. This means that it is not advisable for a strategic transport model to be developed with a large number of small zones like a conventional road traffic model. This is because to be burdened with a large number of traffic analysis zones (i.e. several thousand zones at the neighbourhood level) at the beginning will slow down all data collection, assembly and processing tasks that are related to model zones, complicate the checking and verification of the data, and imply very demanding computer requirements. An appropriate handling of intra-zonal networks and travel costs can help to reduce the pressure of completing the strategic transport model to be set up with numerous small zones at the beginning phase of the model development; the benefits are obvious: numerous small zones do not only increase the data hungriness of model development, but also impose the massive task of network checking and fine-tuning which are more appropriate for later phases of model enhancement.

The use of relatively large model zones (e.g. at the urban district or sub urban district level, which would total several hundred rather than several thousands), however, creates a challenge in estimating appropriately the intra-zonal travel costs. Intra-zonal transport costs are of little practical significance to conventional road traffic models, which in the

main do not include them. But for land use modelling, intra-zonal travel costs are of equal importance to inter-zonal transport costs, because the spatial choices cover all possible zone pairs. Intrazonal flows within large zones are very heterogeneous, because the travel modes available for very short distances (such as within walking distance) are not the same as those beyond reasonable cycling distances (e.g. greater than 5kms). The availability of public transport (e.g. the existence of metro services and the frequency of bus services) may also be very different across zones (e.g. zones in the dense urban core vs those in far suburbs). Such heterogeneity cannot be represented by simple intra-zonal links that are characterised, for instance, by average distances, speeds and costs that mask the critical differences across the distance ranges implied by sub urban district or urban district level zones.

The purpose of the intrazonal supplementary network is therefore to improve the representation of modal availability and characteristics across the entire range of zonal model zone distances, especially where the intrazonal travel distances vary greatly across different flow types, and the zone sizes differ in a marked way in the study area. The method that was first reported in Jin and Williams (2002), later implemented in part of the UK National Transport Model and has been recently improved by Deng (2015, forthcoming) forms the basis for defining the intrazonal road networks. The implementation of such intrazonal network is built into a discrete choice model structure as an extension to the modal choice procedure. Firstly, it requires definition of average characteristics of the transport network by mode and by distance band. Then, for each intrazonal travel demand, it is split into different distance bands. And finally for each band, a modal split is carried out. The intrazonal traffic is not loaded onto the conventional road and rail networks. Instead, the traffic is loaded onto intrazonal network links of different lengths. If the intrazonal distance bands are defined in a detailed enough way, the modelled travel demand (both intra- and interzonal) can be analysed throughout the entire distance band of the study area.

The procedure for setting up the intrazonal distance bands is as follows:

(a) Define distance band types

First, a number of standard distance bands are defined for road travel. Nine bands in total are defined in terms of their distance ranges, mean distance, and the link types to be used

to represent the modal connections within each band. Since the travel speeds on roads in the built-up areas are usually significantly different from the roads in more sparsely populated suburban and rural areas, two types of distance bands for each area are defined.

(b) Define number of bands for each zone

To help determine the number of distance bands for each zone, we need to estimate the radius of a zone and the radius of the built-up area within that zone. Assuming that the shape of a zone is circular we calculate the radius of a zone by measuring the zonal area (in km<sup>2</sup>) in a GIS platform. Zones of irregular shapes are individually checked to make sure the radius estimated is a good representation of the zone. Similarly, the radius of a built-up area is estimated but dependent on the distribution of the built-up area in the zone:

1. If there is one well-defined built-up service centre or the built-up areas within a zone appear to cluster together, then the radius is estimated based on the sum of all the built-up segments, i.e. the envelope of all segments, within the zone.
2. If the built-up areas within a zone are dispersed and form separate urban centres, the radius of the largest urban centre is calculated and used to determine the number of distance bands needed.

The estimation shows that the radius calculated from (2) is less than or equal to that from a). Since very often the built-up areas within a zone are neither uniquely centred nor entirely separated, the appropriate radius would be in between the two values. Therefore, each zone was individually examined. In most cases the measure of (1) is found to be a more appropriate measure. In dense urban areas where the zone is totally built-up or when large parks are present and deducted, the radius of the built-up area is equal to that of the zone as a whole. Where the built-up areas have a degree of separation, a value between the two values is chosen.

### **3.5 Scenario tests**

As with all models, this model is a simplified representation of some aspects of reality, but hopefully it is not only theoretically sound but also sufficiently robust to yield practical results in terms of appraising planning and design options in a rigorous manner. This model is not meant to serve as a crystal ball which is able to accurately predict the future but more as a tool for conducting systematic analysis of questions of 'what if'. This means

alternative scenarios can be tested and evaluated within the model via a process of comparison. This is realised by comparing the results of a base run or reference case with alternative scenarios at each point in time.

## Chapter 4 DATA, MODEL CALIBRATION AND VALIDATION

### 4.1 Overview

The purpose of this chapter is to present the comprehensive application of the methodology. The methodology is implemented on the MEPLAN package.

This chapter aims to test a comprehensive application of the methodology by implementing it for Taichung. There are four main reasons for choosing this case study area.

First, Taichung exemplifies the travel demand shift occurring throughout the world. Many cities in Asian have night markets dedicated to eating, shopping and socialising. In recent years, the night markets in Taiwan have been promoted as tourist attractions therefore many places have become even more crowded (Figure 4-1 and Figure 4-2). In addition to the Asian cities, many cities in the world have increasing night market activities. London recently saw its first night underground services running to meet the demand for the capital's night market activities and help ensure London thrives as a 24-hour city. Other cities such as Amsterdam and Paris have already appointed a night time mayor to manage the night time activities to reconcile the demands and concerns for various stakeholders in the city.

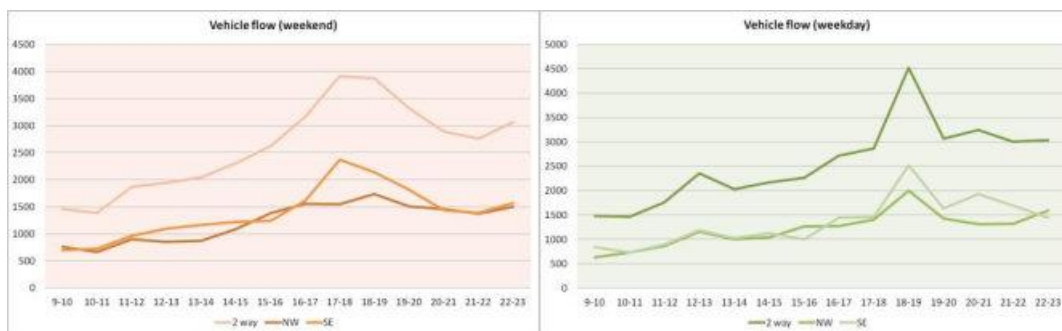


Figure 4-1 Vehicular flow recorded near Feng-Chia night market in Taichung  
Source: Ho, 2012



Figure 4-2 Traffic at Feng-chia night market at 8:30(Left) and 22:00(Right)  
Source: Ho, 2012



These places are facing the common challenges relating to surging demand for urban space and infrastructure in a new dimension. Improved coordination and integration of land use, transport and urban design is expected to play an important role in curbing the rise in overall resource consumption, cutting pollution levels and developing a more environmentally sustainable approach to economic development and social welfare.

Secondly, Taichung has a mixed-use urban regeneration area in the city centre which not only anticipates a significant change in demographics for the city in the long run but also a shift in travel demand at night.

Thirdly, Taichung has recently undergone an administrative restructuring by merging with the former Taichung county region and become a much bigger conurbation in central Taiwan. Thereby the government sets out to make Taichung a place which can be economically competitive against other cities in the region as well as a place where the development between former Taichung city and country area is well-balanced.

Lastly, the author of this dissertation comes from Taichung and has access to the data needed for model building and the local knowledge of the place which makes it more straightforward to conduct a case study for the research.

Figure 4-3 below shows the model zones used for the case study area in Taichung. The model contains 253 zones covering 2010.92 km<sup>2</sup>, which include all of the Taichung metropolitan area for planning purposes. The zone structure is compatible with the geographical definition of the 2010 population census data. The area south of Taichung is included in the model because it is within the Taichung commuter catchment. For the urban core area which has higher population density, there are 86 zones representing it, the extent of which is 162.31 km<sup>2</sup>. The average size of each zone in urban core area is 1.89 km<sup>2</sup> and the average number of households is 4540. The zones for the rest of Taichung and those outside of Taichung are less densely populated. The total extent of the rest of the Taichung is 1035.11 km<sup>2</sup> represented by 96 zones. The average size of each zone is 10.78 km<sup>2</sup> and the average number of household of each zone is 5080. For the area outside of Taichung municipality, the total extent of this area is 813.50 km<sup>2</sup> represented by 71 zones. The characteristics of each zone is similar to those in the rest of Taichung. The average size of each zone is 11.46 km<sup>2</sup> and the average number of household of each zone

is 5484. The zoning design used here compares well with relatively detailed land use and transport model. Appendix 1 presents further details of the zoning system used in this model.

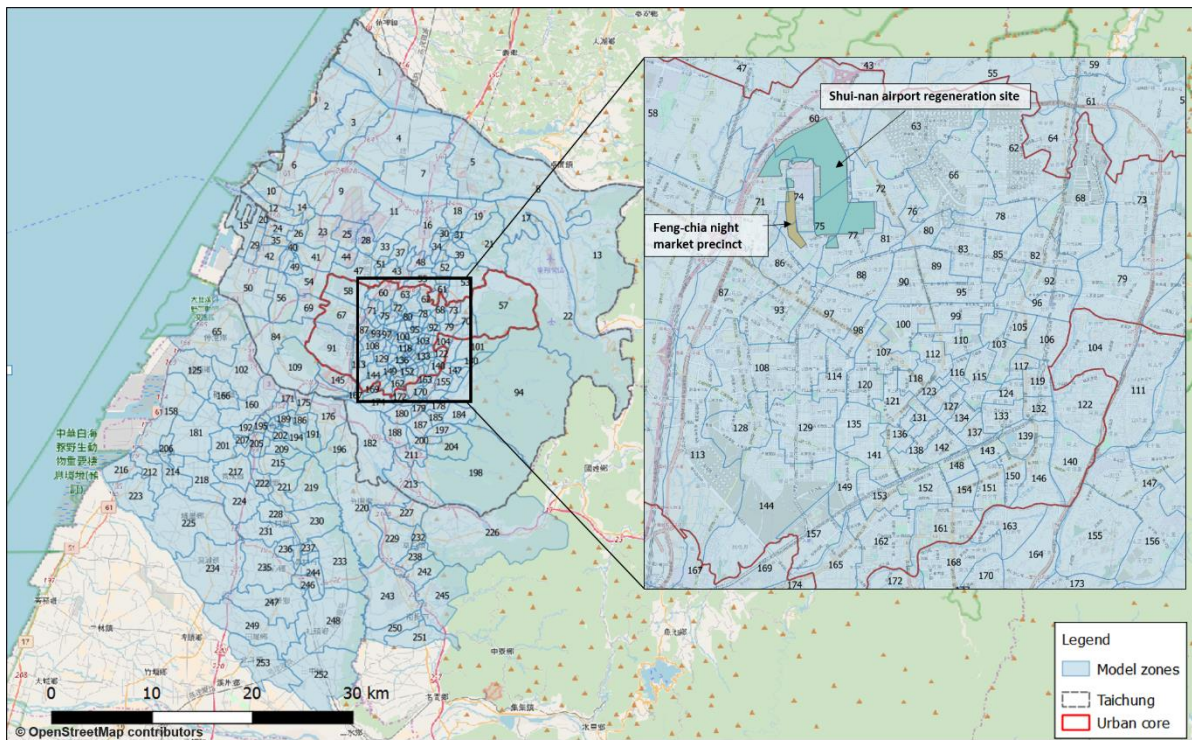


Figure 4-3 Zoning system for the case study area in Taichung

## 4.2 Data sources

The above model structure is established based on the available datasets. For the conventional activities, the main datasets used are the Taichung metropolitan area road network planning report (CECI, 2009) and the TransCAD model accompanying the report which provides data on households and households' demand coefficient and the parameters for determining the attractiveness of conventional activities; Taichung household travel survey (DORTS, 2016) on trip length distribution and modal split data for calibration of the spatial distribution model and the modal split model for conventional activities. For night market activities, 2010 population census data is used for setting up the home-based demand from residents, CECI (2009)'s employment and student data for setting up non-home based demands while data from Tourism Bureau of Taichung (2014), TaiwanStay (2014), Foursquare(2015), TripAdvisor(2015) and Airbnb(2015) for estimating tourist number. Data from dissertation of Yen(2011) is used for estimating night market demand coefficient. Other data from IPeen(2015) and TripAdvisor(2015) is used to determine the attractiveness of the night market activities

which is the important part of calibrating spatial distribution of night market activities; Feng-chia commercial centre yearly survey (Lee et al., 2015) provides market visitors' profile and modal split for calibrating both the spatial distribution and modal split for night markets activities.

The main calibration tasks for the year 2013 are:

(a) determine the demand coefficient for households to work, school, other private travel and business travel; determine the demand coefficient for individuals (residents and tourists) to night time activities.

(b) input constraints for households for day time activities; input constraints for individuals (residents and tourists) for night time activities.

(c) Calibrate spatial distribution models of households for journeys to work, school, other private travel and business travel; calibrate spatial distribution models of individuals (residents and tourists) for journeys to night time activities.

(d) Model verification and validation

Figure 4-4 shows the model structure and data used for setting up and calibration of the model.

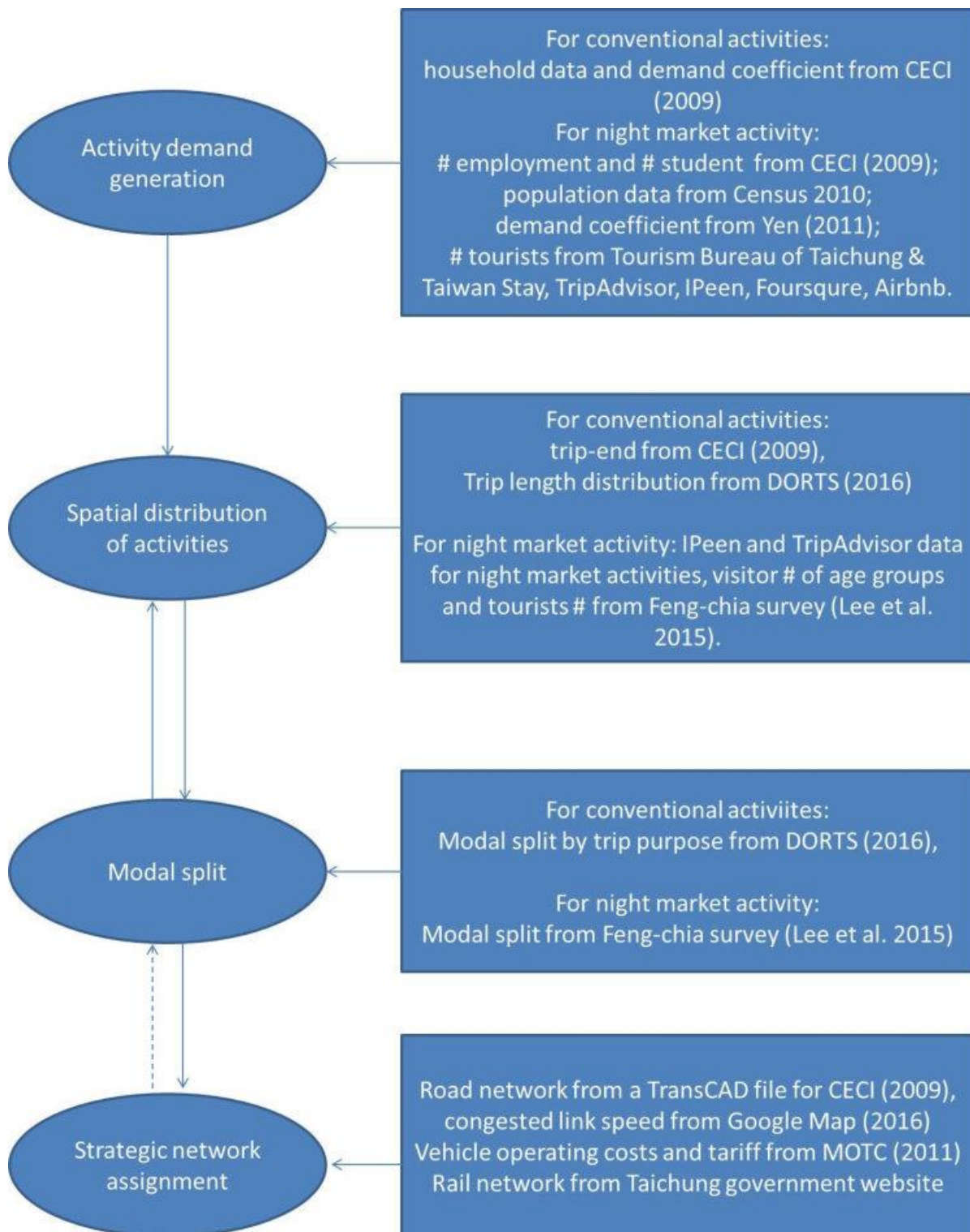


Figure 4-4 Model structure and data for the Calibration Year 2013

#### 4.2.1 Feng-chia survey

The Department of Statistics of Feng-chia University has conducted an annual survey on the visitors to the Feng-chia commercial centres since 1998. Survey data, collected in the end of 2014 and published in 2015, has been obtained, which has been used to inform the model. This data is based on substantial number of respondents, 1324, and is considered

a good starting point to understand demographic and behavioural characteristics of visitors to night markets across Taichung. Other survey data from dissertations and research projects are used to complement the Feng-chia survey.

Figure 4-5 shows 61.9% of the respondents from Feng-chia survey are Taichung residents. Another 34.5% of them are domestic tourists while 3.7% of them are overseas tourists. Another survey undertaken by Chen and Wang (2009) on the visitors' behaviour to Taichung commercial centres shows that Feng-chia commercial centre has the highest share of tourists of all commercial centres in Taichung (Figure 4-6). This is further supported by the scraped IPeen data (Figure 4-7) which will be discussed in detail later. The variation of shares among the commercial centres shown by these two figures means that the tourists and the residents have different preference as to where to visit in Taichung. Thus, it is worth considering the tourists' movement separately in the model.

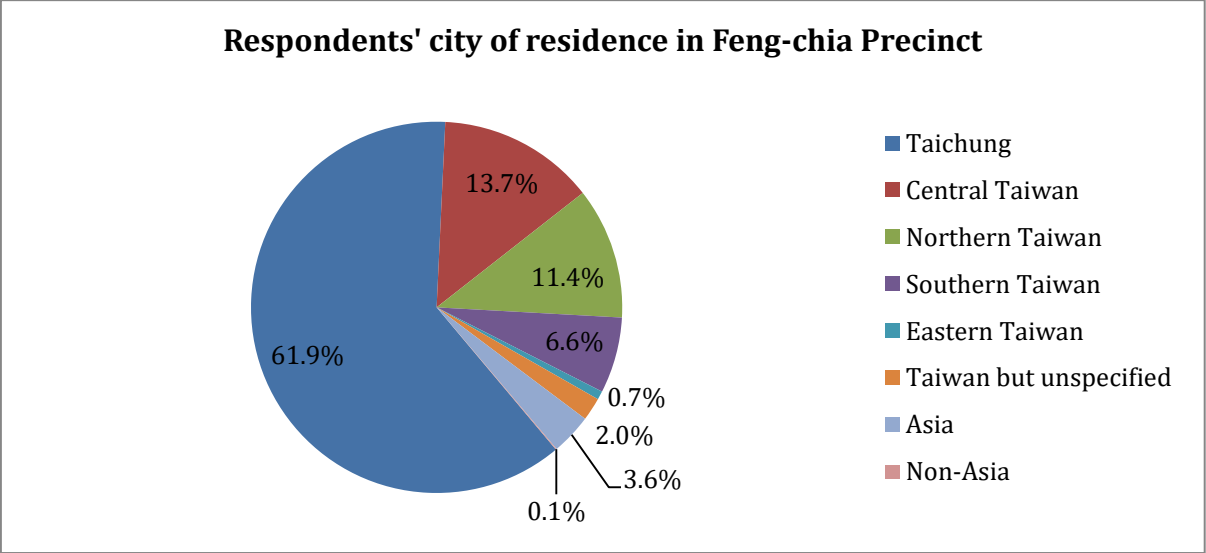


Figure 4-5 City of residence based on Feng-chia survey (2014)

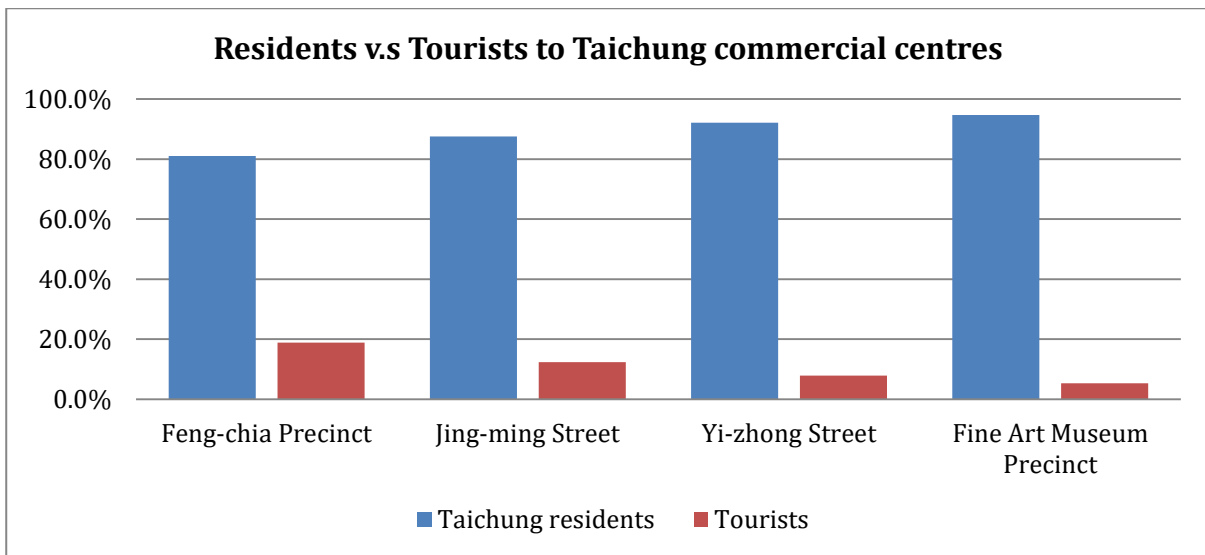


Figure 4-6 Share of residents and tourists in some commercial centres in Taichung based on Chen and Wang (2009)

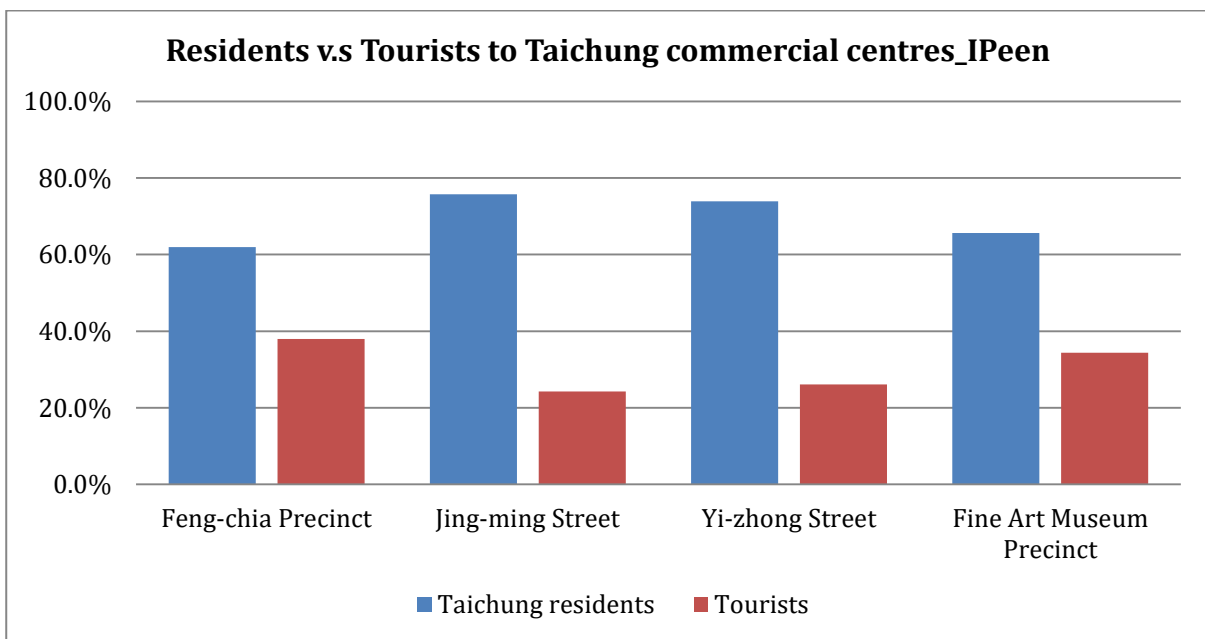


Figure 4-7 Share of residents and tourists in some commercial centres in Taichung based on scraped IPeen data (2015)

From the above Figure 4-7, it is found that IPeen data not only supports the proposition of treating residents and tourists differently in the model, but also that the share of residents to Feng-chia area, 62.0%, coincides with the share from Feng-chia survey, 61.9%. Also, the increase in tourists' shares of Yi-zhong Street precinct and Fine Art



Museum precinct from the 2009 survey data was captured by IPeen which reflects the increased popularity of these two commercial centres by tourists due to the recent tourism development in Taichung. Thus, the emerging data source can be a good alternative to understand the visitors' background and preferences.

Figure 4-8 below shows the comparison of modal shares from the Feng-chia survey and two other surveys. The figure shows that the motorcycle has been the most popular transport mode with car being the second. Public transport and walking make up the rest of the share. The overall trend is for the modal splits to be more evenly distributed. There is a big drop in motorcycle use while public transport use has been increasing over the past decades. This modal share is used in model split calibration for the model.

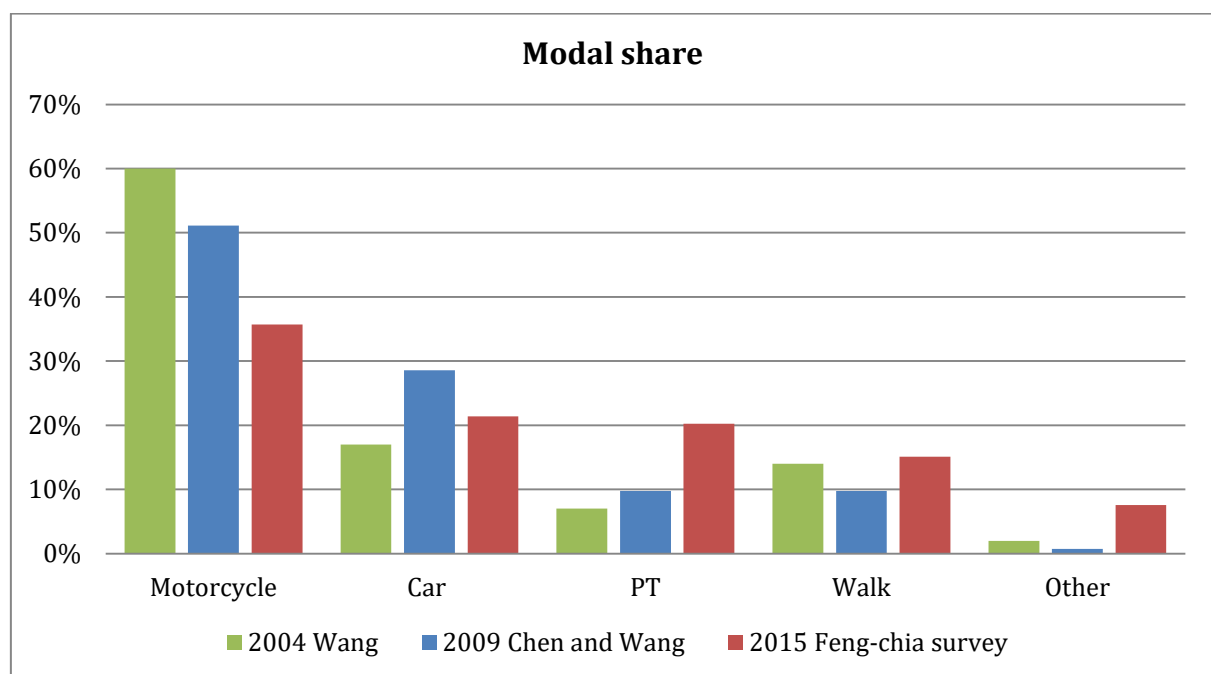


Figure 4-8 Modal share comparison

Figure 4-9 below shows the age shares of visitors to Feng-chia commercial centre from different sources. The age segmentation of the first two surveys is different than that from the Feng-chia survey. However, the first two surveys done in 2004 and 2012 and are based on 117 and 216 respondents respectively so a larger error margin is expected than in the Feng-chia survey. Therefore, the age segments from Feng-chia survey is used for modelling night market activities as it is the most up to date and has the largest sample size.

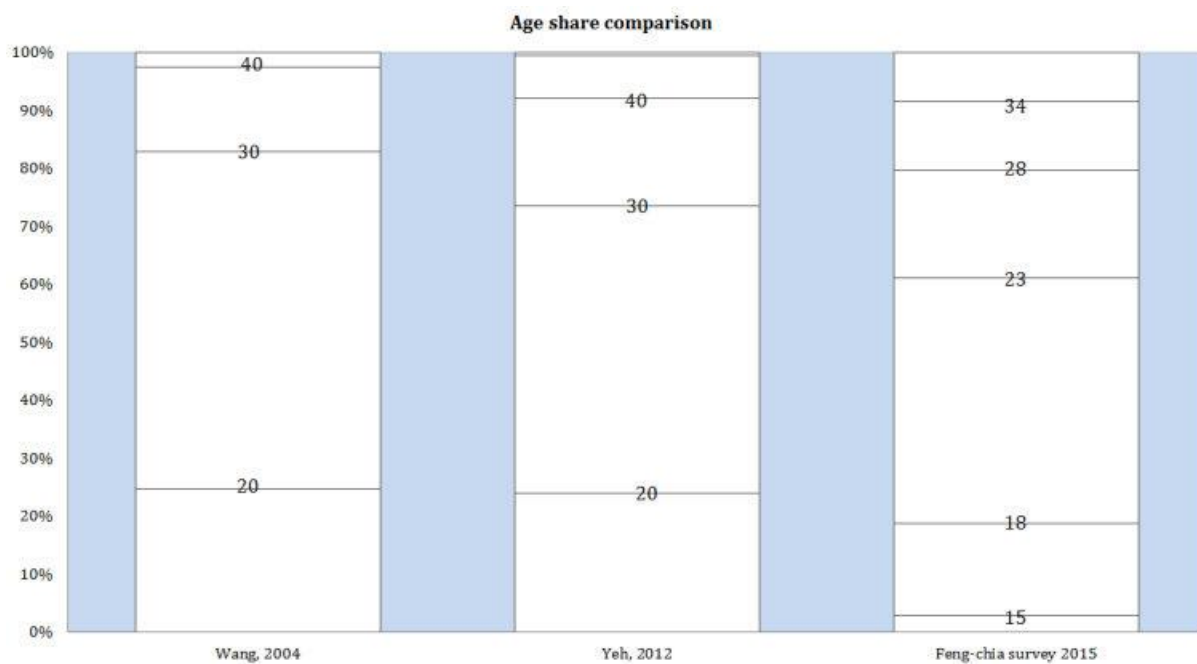


Figure 4-9 Age share comparison

#### 4.2.2 Social media data

IPeen is Taiwan's biggest food and beverage information platform. The company applied a gaming-style levelling and virtual currency system, classifying members into seven categories based on the number of articles contributed and the articles' quality which is determined by a voting system open to all members. The levels are named after those used for the exam system in imperial China, ranging from Tongsheng—one who has yet to pass the county level exam—at the bottom through Xiucan—one who has passed the county level exam—and up to Zhuangyuan—top scorer in the palace exam and the highest possible ranking.

In April 2015, 8347 point of interests and their 33083 comments in Taichung were scraped. These comments were contributed by 1076 users. Figure 4-10 shows the composition of the users by level. Half of these users are at the lowest level and the proportion of users shrinks with each consecutive rank. However, the numbers of comments left by higher ranking users make up more than 50% of the comments (Figure 4-11). On average, each Zhuangyuan rated user, will make 1900 comments while the lower ranking users such as Xiucan and Tongsheng average 60 and 30 comments respectively (Figure 4-12). These figures show that more comments are made by relatively few yet highly rated users which indicates that the comments are of a high standard and therefore the data is considered valid to be used for the model.



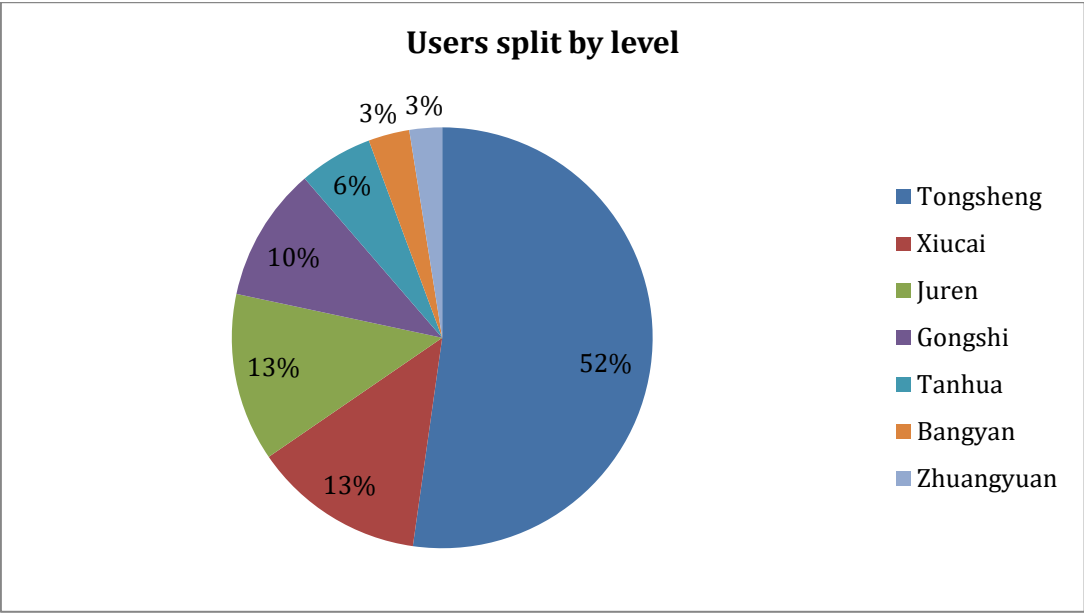


Figure 4-10 Number of IPeen users by level

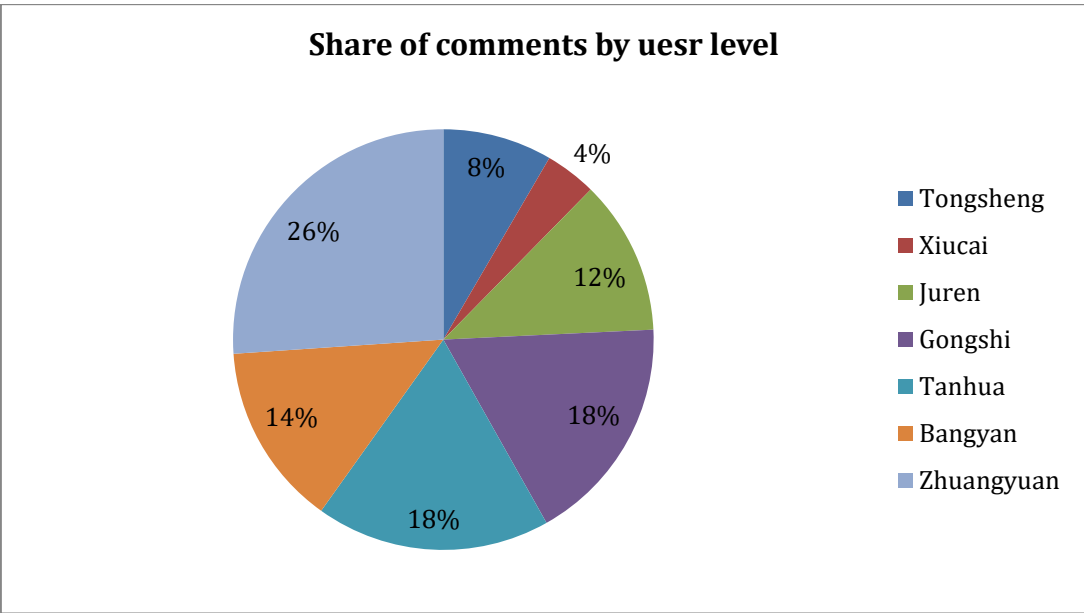


Figure 4-11 Number of comments by user level

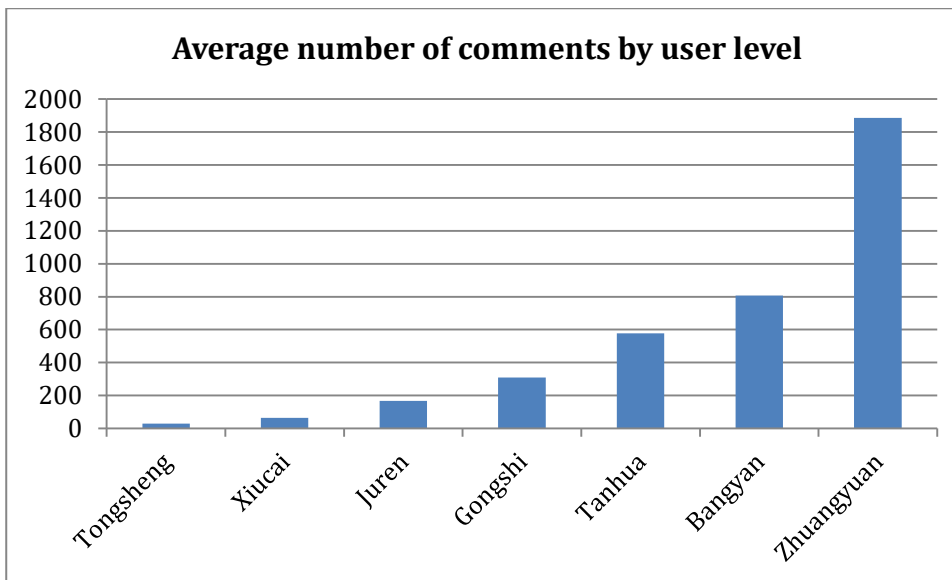


Figure 4-12 Average number of comments by user level

Information provided by the website also includes the average spend per shop recorded by the reviewers. Figure 4-13 below summarises the share of average spend per reviewer in each shop. For most shops, each reviewer spent under New Taiwan Dollar 200, which is equivalent to 4.8 pounds based on the exchange rate in August 2016. This suggests they are mostly small independently-run shops or vendors that are often not included in the conventional survey as part of the preparation of setting up travel demand models. Therefore, the IPeen data can be seen as complementary to the conventional method of determining the attractiveness of an area in terms of leisure activities that induce discretionary travel.

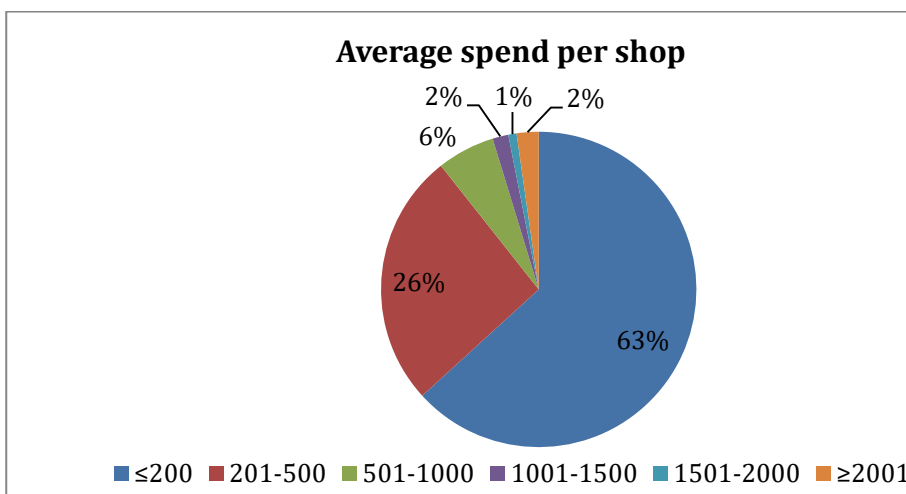


Figure 4-13 Average spend per shop

We established the need to treat residents and tourist demand differently; however, it is found that from above figure only 38% of the reviewers from IPeen are tourists. This prompts us to investigate another website, TripAdvisor, a popular review website for inter-city travel information in Taiwan as well as a good source of information for international travellers as the website has multi-language support and well-known for people outside of Taiwan.

The sections on TripAdvisor relating to night market activities in are restaurants and shopping areas. The comments and the city of residence of the reviewers are scraped. The analysis of restaurant comments shows that 61% of the comments are left by tourists (Figure 4-14) out of 2136 comments. Most of them are travellers from Taipei or nearby cities followed by overseas tourists which make up 14% of the reviewers. This share of tourists is higher than the share found from the IPeen data. For shopping comments, it is found that most comments are left by tourists. Therefore, the number of comments from restaurant and shopping categories were both used to help determine the attractiveness of each zone for tourists.

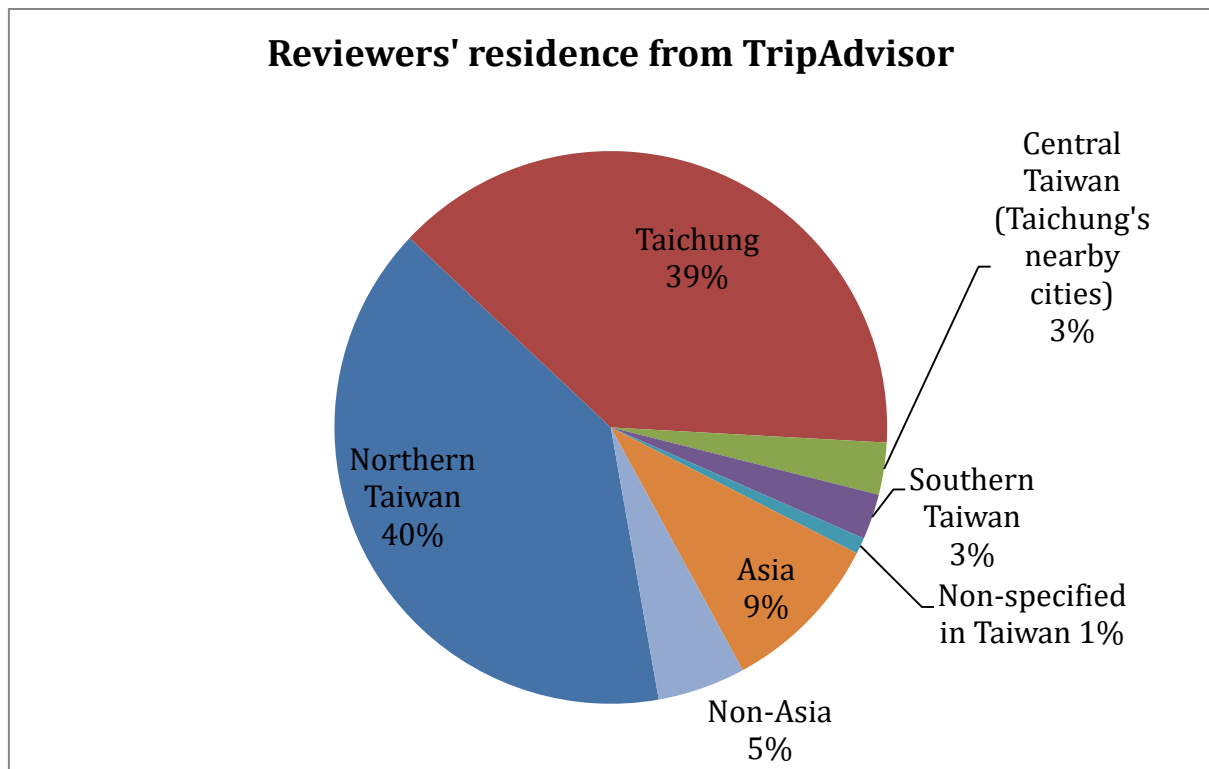


Figure 4-14 Tourists' residence based on food reviews in TripAdvisor

### **4.2.3 Web data extraction**

Most of the data extraction was done with R, an open source programming language, with the aid of rvest, an R package which makes it easy to scrape data from html web pages.

To start with, the content of the page is downloaded and parsed with `read_html()`. Then one can select the html element one is interested in by passing its name into `html_node()` together with the page content. Finally `html_text()` can be used to retrieve the text content of the html element.

In addition to R, we also used the Excel function “From Web” to get data from the webpage because the design of the website of the TripAdvisor made it difficult to extract location through R, due to log-in restrictions. While R enabled us to automate the extraction of the majority of the data, Excel was a useful complement to this in cases where the data was harder to access.

After extracting the data from the website, we started to inspect the validity of the data. For example, more than 38000 comments were scraped from IPeen. On closer look, more than 4000 of them were deemed invalid. Most of these were because the commercial establishments concerned had gone out of business but remained listed on the website. The second reason was that some of the comments did not include the shops’ location data, i.e. either address or latitude/longitude on the website. Eventually, the raw data was cleaned and only the valid data (33083 comments) was fed into the model.

## **4.3 Land use model**

### **4.3.1 Conventional activities**

#### ***4.3.1.1 Conventional activity generation***

The specification of conventional activities is based on households typed in the CECI report. There are 20 types of households of five household income levels and four vehicle ownership types (Table 4-1) with income level A being the lowest and vehicle ownership I being households that own no vehicles. The demand coefficients for each type of household are based on the trip rates extracted from the CECI report. Table 4-1 also gives the demand coefficients for each type of household by activity.

Income	Vehicle ownership	Household type	HBW	HBE	HBO	NHB
A	I	HH type 1	0.74	0.69	0.65	0.13
A	II	HH type 2	1.08	0.99	0.86	0.28
A	III	HH type 3	1.43	1.35	1.10	0.33
A	IV	HH type 4	1.47	0.94	1.13	0.47
B	I	HH type 5	1.26	1.17	0.56	0.19
B	II	HH type 6	1.43	1.25	0.84	0.33
B	III	HH type 7	1.90	1.29	1.08	0.41
B	IV	HH type 8	1.77	1.35	1.40	0.29
C	I	HH type 9	2.04	0.77	0.64	0.51
C	II	HH type 10	1.57	1.59	0.83	0.27
C	III	HH type 11	2.38	1.24	1.11	0.55
C	IV	HH type 12	2.13	1.11	1.30	0.62
D	I	HH type 13	2.33	0.80	0.53	0
D	II	HH type 14	2.14	1.23	0.49	0.18
D	III	HH type 15	2.88	1.05	1.15	0.58
D	IV	HH type 16	3.06	0.91	1.23	0.69
E	I	HH type 17	2.09	0.60	0.68	0
E	II	HH type 18	1.35	1.47	1.07	1.16
E	III	HH type 19	3.49	0.97	1.23	0.77
E	IV	HH type 20	3.55	0.85	1.42	0.47

Table 4-1 Demand coefficient of various conventional activities by household type

#### 4.3.1.2 Spatial interaction process of conventional activities

As described in chapter 3, what follows activity generation is the spatial interaction process. The term influencing the attractiveness for each type of conventional activity is also extracted from the CECI report. Table 4-2 summarises the values of the parameters corresponding to  $S_i^n = Constant^n + a^n E1_i + b^n E2_i + C^n P_i$  [Equation 3.3]. The number of students and employees in each zone is extracted from the TransCAD file supporting the CECI report.

Type of activity	Constant	Parameter $a^n$	Parameter $b^n$	Parameter $c^n$
Work	7.107	1.966	1.561	-
Other	9.912	-	0.205	-
Non-home based	0.651	-	0.205	-
Education	-	-	-	1.57

Table 4-2 Parameters for estimating the attractiveness of a zone

#### 4.3.2 Night market activities

As clear from the data discussed previously, night market activities are favoured by not only the residents but also the tourists and they have different preferences in locality. Therefore, the model is set up to treat residents and tourists separately.

##### 4.3.2.1 Residents' demand for night market activities

According to section 3.2.2.1, the visitors to the night markets are segmented by age group. The formation of population in each zone by age group,  $Pop_j^a$ , is achieved by aggregating the data into specified model zones from population census data which uses Li, the smallest administrative unit in Taiwan. The residents are segmented into 8 age groups based on the age segmentation used in Feng-Chia survey (Lee et al., 2015) to ease subsequent modelling tasks.

According to the survey conducted by Yen (2011) on night markets in Taichung, the average frequency of people going to the night markets is every 3.9 days. The inverse of this frequency, 0.256, essentially equates to the average demand coefficient for night markets per person per day in the model. However, there is no further information on the visiting frequencies by age group in the literature. Therefore, the estimation of the demand coefficient of each age group,  $t_a$ , is needed. The process is an iterative one. First, an initial set of reasonable demand coefficients for each age group is identified. Then the percentages of people in each age group from Feng-chia survey are taken as fixed shares and different combinations of demand coefficients for each age group is multiplied with these values of shares until the weighted average of the demand coefficient is close to 0.256.

The initial set of demand coefficients is determined based on the literature review (Chen and Wang 2009; Yen, 2011) showing that people aged between 20 and 29 make up the majority of the visitors to night markets in Taichung. Thus, initial demand coefficients of 0.33, analogous to going to the night market every 3 days, are set for age groups 20-24 and 25-29. On the other hand, people aged over 60 are assumed to visit night markets with a low frequency thus a low demand coefficient of 0.01, which translates into visiting night markets every 90 days, is set as initial value for this group. After several iterations, the process results in a weighted average of 0.247. The values of the demand coefficients for each age group is shown in Table 4-3.

Age group	Share from Feng-chia survey	Demand coefficient to night markets ( $t_a$ )
00-14	3%	0.0400
15-19	15%	0.2500
20-24	50%	0.3333
25-29	18%	0.2000
30-34	7%	0.0500
35-39	4%	0.0333
40-59	2%	0.0167
60+	1%	0.0111
Weighted trip rate	-	0.247

Table 4-3 Estimated demand coefficient for night market activity for residents

As explained in chapter 3, the demand for night market activity is in fact required for people who are based at homes from which the trips will be made and by people who are based at workplaces/schools from which the trips will be made. Therefore, the above demand coefficients will need to be split into home based demand coefficients and non-home based demand coefficients. The former is for people who will travel from home and the latter for people who will travel from workplaces/schools. This is achieved by determining the percentages of people of each age group who will travel from home,  $p_a$  in Equation 3.5.

This process of determining  $p_a$  is also an iterative one and carried out simultaneously with the spatial distribution model for residents and the modal choice model (see 3.2.2.2 and 3.4.1). Firstly, an initial set of reasonable  $p_a$  is decided. People in age group 25-29 are considered the most likely to socialise with friends or colleagues straight after work since they may be the group that is most free from family obligation. The older or the younger the people are, the more likely they would travel from home. Secondly, an initial set of reasonable concentration parameters,  $\lambda^a$ ,  $\lambda^{student}$  and  $\lambda^{employed\ worker}$  are defined. Again, people of age group 20-24 are considered to travel the furthest from home to meet their demand for night market activity since they are the most epicurean cohort and have the means, as such private vehicles and income, to do so. This same idea is applied when we determine the concentration parameters for employees and students with the former have having a lower concentration parameter because they are believed to be more mobile than the students due to the ownership of private vehicles and disposable income. People who travel from work places are assumed to be made up of people from age groups of 25-29, 30-34, 35-39 and 40-59. People who travel from school are assumed to be made up of people from age groups of 0-14, 15-19, and 20-24. Therefore, we can work out the

demand for each group by aggregating the demand by the corresponding age groups. Subsequently, the demand coefficient for each occupation can also be deduced.

The goal is to find the combination of  $p_a$ ,  $\lambda^a$ ,  $\lambda^{student}$  and  $\lambda^{employed worker}$  as well as  $\Omega_h^s$ , mode specific constants, which would satisfy the following two constraints:

- The first constraint is the total number of residents of Taichung, 13440, going to Feng-chia night market. This is based on Feng-chia survey (2015) which finds that 64% of respondents are Taichung residents for a weekday, and the estimated total daily number of visitors is 21,000.
- The second constraint is for the share of the younger age group cohorts to be 68% and the older cohorts to be 32%. This is based on the aforementioned shares extracted from the Feng-chia survey (Figure 4-15).

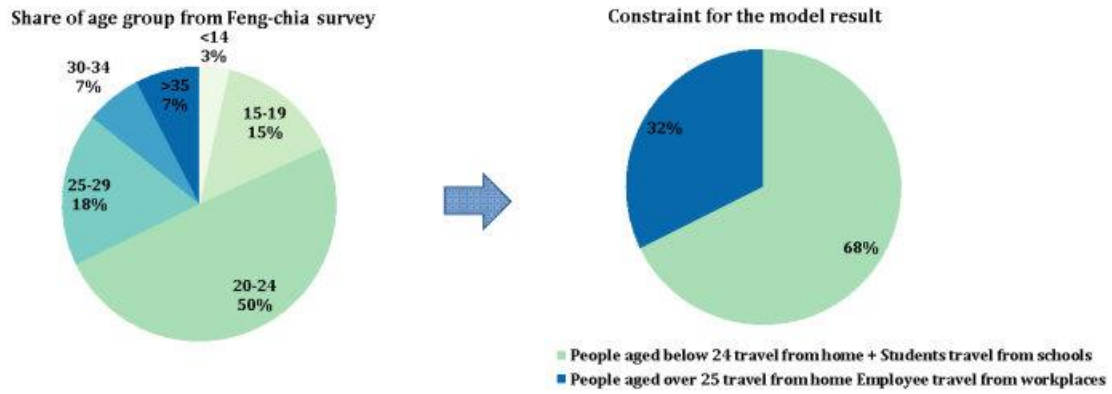


Figure 4-15 Shares of age group as constraints for calibration of spatial allocation model of night market activity

The mode specific constants,  $\Omega_h^s$ , have less bearing on the dynamics of the model than other parameters and will be described in the later section. Table 4-4 below summarises the shares of people travelling from home, the corresponding demand coefficients, and the concentration parameters. Table 4-5 shows the non-home based demand coefficients and concentration parameters.



visitor code	age group	% travelling from home ( $p_a$ )	Home based demand coefficient ( $th_a = t_a * p_a$ )	Concentration parameter $\lambda^a$
41	00-14	86%	0.0343	0.120
42	15-19	50%	0.1250	0.070
43	20-24	45%	0.1500	0.035
44	25-29	30%	0.0600	0.070
45	30-34	40%	0.0200	0.055
46	35-39	60%	0.0200	0.055
47	40-59	70%	0.0117	0.150
48	60+	100%	0.0111	0.100

Table 4-4 Demand coefficients and concentration parameters for home based demand

Occupation	age group	% travelling from work/school ( $1 - p_a$ )	Demand from workplaces/schools $Y^a * (1 - p_a)$		people	student/employee Demand coefficient	Concentration parameter $\lambda_{student} / \lambda_{employed\ worker}$
Student	00-14	14%	3785	93,734	758,941	0.124	0.08
	15-19	50%	36727				
	20-24	55%	53222				
Employee	25-29	70%	46957	67,290	1,171,598	0.057	0.05
	30-34	60%	10482				
	35-39	40%	4020				
	40-59	30%	5830				
-	60+	0%	0	-	-	-	

Table 4-5 Demand coefficients and concentration parameters for non-home based demand

#### 4.3.2.2 Tourists' demand for night market activities

As describe in 3.2.2.3, to estimate tourists' demand for night market activities involves estimating the numbers of tourists and the location of their stay and where the attractions are for the tourists in a similar fashion to the activity generation and spatial allocation process as described in the previous section for Taichung residents. As night market have been recorded as the most visited tourist attraction by international tourists (Taiwan Tourism Bureau, 2015a) and Feng-chia night market in Taichung as the fourth most

visited tourist attraction by domestic tourists (Taiwan Tourism Bureau, 2015b) as well as the fact that many tourists go out to eat which is very likely to be close to night market when they visit Taichung, it is assumed that the demand coefficient,  $tt$ , used in Equation 3.12 for night markets activities by tourists is equivalent to 1, meaning all the overnight tourists make trips to night markets once per day. Therefore, the succeeding sections only show how the data is used following on from the methodology described in 3.2.2.3 which involves making use of four types of data to estimate number of overnight tourists in each zone. The data sources used to estimate  $Popt_j$  are: Tourism Bureau of Taichung, TaiwanStay, TripAdvisor, IPeen, Foursquare, Airbnb and the Feng-chia survey. Firstly, the Tourism Bureau of Taichung provides official statistics on the tourism industry in Taichung while TaiwanStay is a website listing tourist accommodation establishments registered with Tourism Bureau of Taiwan. Since both data are official statistics so the information from TaiwanStay tally with the data from the Tourism Bureau of Taichung and are used in conjunction for estimation. TripAdvisor, IPeen, Foursquare are travel-related websites used by accommodation establishments to advertise their business and are popular with tourists making their bookings in Taiwan. TripAdvisor and Foursquare also operate in many other cities of the world so the estimation method can be used for any city listed on the websites. Thirdly, Airbnb is an online platform that enables people to rent out their vacant rooms or homes while they are away. This website has become very popular recently in Taiwan when it comes to rent a holiday accommodation with more than 10000 listings in Taiwan as of October 2015. As for its usage outside of Taiwan, more than 34000 cities in the world have users of this website. In total there are more than 2 million rental listings in the world on the Airbnb website so it represents a significant number of accommodation spaces even though this type of accommodation is more informal than the ones listed on other websites. Lastly, the Feng-chia survey has been utilised since data on the number of people staying at friends and family has been captured.

#### 1. Estimation with official statistics:

The Tourism Bureau of Taichung has published a dataset titled “Report on Tourist Hotel and Home Stay Facilities Operations”. This dataset records the total number of guests (persons) for each type of accommodation establishment each year across Taichung. Therefore, the average daily guest number can be derived by dividing the yearly figures by 365, corresponding to  $G^a$  in Equation 3.13, as shown in Table 4-6.

Type of accommodation establishment	Reported number of guests for year 2014	Estimated number of guests per day ( $G^a$ ) for all establishments
International Tourist Hotels	454,106	1,244
Tourist Hotels	179,282	491
Hotel Enterprises	5,452,184	14,937
Home Stay	31,358	86
Total	6,116,930	16,759

Table 4-6 Estimated number of guests per day for all establishments by type

However, data from Tourism Bureau of Taichung alone is not disaggregate enough to be able to estimate how many tourists stay in each establishment or to indicate the location of these establishment. Thus, a dataset from TaiwanStay website containing more detailed data is used in conjunction for the estimation. On the TaiwanStay website, data includes names of 383 accommodation establishments, the corresponding types and number of rooms is ready to download in an excel spreadsheet. As mentioned earlier, these two datasets are both official records so the types of accommodation establishment from these datasets are found to be the same. Besides, GoogleSheet's function ImportXML has also been utilised to scrape the latitude and longitude of each accommodation establishments and GIS tools have been applied to identify in which zone the accommodation establishments are located.

Table 4-7 below lists some data examples from TaiwanStay and the associated zones.

Index	Name	Type	No. of rooms	Latitude/ Longitude	Model zone
1	歐風商旅	Hotel Enterprises	36	24.1651/ 120.6406	93
2	西悠飯店 台中店 CU HOTEL	Hotel Enterprises	140	24.1632/ 120.6757	93
3	通豪大飯店	Tourist Hotel	226	24.1677/ 120.6728	90
4	昭月民宿	Home Stay	3	24.1945/ 120.8558	13

Table 4-7 Examples of data from Tourism Bureau of Taichung and TaiwanStay

These numbers form the basis for allocating the aggregate data of number of tourists according to accommodation types onto each zone by using Equation 3.13. Table 4-8 gives

some examples of the allocated number of tourists in each zone based on these two datasets.

Model zone	Number of guests per night ( $g_j^a$ )			
	International Tourist Hotel	Tourist Hotel	Hotel Enterprises	Home Stay
3	0	0	132.7	0.4
4	0	0	61.1	5.1
5	0	0	28.6	3.4
Total	1,244	491	14,937	86

Table 4-8 Number of guests per night by type of accommodation establishment

## 2. Estimation with data from travel-related review websites:

Apart from official data on accommodation establishments, the listings from other websites are also explored to complement the data since sometimes the government data was not always up to date and reflective of changes in the industry. For this research, the popular websites in Taiwan were identified with local knowledge and in the end, the 226 listings from TripAdvisor, 376 from IPeen and 294 from Foursquare were scraped, combined with the TaiwanStay dataset and deduplicated. The removal of the duplicate data was done by applying the fuzzy matching, a function in Excel, with regard to the names of hotel establishments. The reason for using fuzzy matching is because the names displayed on the different websites for the same hotel may not be 100% the same so the fuzzy matching was a good tool for identifying correspondences between segments of displayed names. The procedure started by, firstly, taking TripAdvisor as a target dataset and IPeen as a comparing dataset and comparing them with fuzzy matching technique. A variable of similarity rates would appear next to each name of accommodation establishment from TripAdvisor. If the similarity rate attached to a name from TripAdvisor was 100%, this means there is an exact name match with the IPeen dataset. Any rate lower than that means there was no exact name match between two datasets however similar matches exist. The results showed that rate above 70% indicated the name from TripAdvisor has similar enough match from IPeen for the listing to be identified as a duplicate. So, with this method a combined list of names without duplicates from these two datasets was formed. The procedure was repeated between this combined dataset and two other datasets, Foursquare and Taiwanstay, until a combined final list containing no duplicates was formed. The types based on official classification, as presented in Table 4-6, were also identified for each accommodation establishment. As

with TaiwanStay dataset, each accommodation establishment from these datasets are allocated to the corresponding zone with the scraped latitude and longitude. Table 4-9 below lists some data examples and the associated zones.

Index	Name	Type	Latitude/Longitude	Model zone
1	科博涵宿館	Home stay	24.1512/120.6718	118
2	逢甲斜角	Home stay	24.1759/120.6374	71
3	Champs Hotel	Hotel Enterprises	24.1540/120.6701	107
4	Charming City Hotel	Hotel Enterprises	24.1719/120.6908	85
5	Taichung Box Design Hotel 台中博客 創意旅店	Hotel Enterprises	24.1520/120.6860	115

Table 4-9 Examples of scraped data from TripAdvisor, IPeen and Foursquare and the corresponding model zone

Table 4-10 shows, at zonal level, the number of accommodation establishments by type.

Model zone	Number of accommodation establishment ( $E_j^a$ )	
	Home Stay	Hotel Enterprises
7	0	1
13	1	0
74	7	4
75	7	1
86	4	3

Table 4-10 Some zones with the number of accommodation establishments listed on TripAdvisor, IPeen and Foursquare

As described in 3.2.2.3, official dataset, such as the Tourism Bureau statistics for this research, should be used to complement this type of online dataset. So it is derived that the average number of guests per night in each type of accommodation establishments are 56.58 and 1.28 respectively (Table 4-11).

Data from Tourism Bureau of Taichung	Home stay	Hotel Enterprises
No. of guests per night	86	14937
No. of establishment	67	264
Estimated number of guests per establishment per night ( $g^a$ )	1.28	56.58

Table 4-11 Data from Tourism Bureau of Taichung and the derived number of guests

By applying Equation 3.14, the number of tourists staying in each zone by accommodation establishment type is derived. Table 4-12 below shows some zones with the number of guests by accommodation establishment type.

Model zone	Number of guests per night ( $g_j^a$ )	
	Home Stay	Hotel Enterprises
7	0	56.58
13	1.28	0
74	8.98	226.33
75	8.98	56.58
86	5.13	169.74

Table 4-12 Some zones with the number of tourist by accommodation establishments type

### 3. Estimation with data from peer-to-peer rental platform:

In Taiwan, peer-to-peer rental platform Airbnb has become very popular so information from this website as described in 3.2.2.3 is scraped for estimation. Table 4-13 shows some data scraped from Airbnb for some listings including the number of guests allowed per night and the corresponding zones identified with GIS based on the scraped latitude and longitude.

Index	Property Name	Number of guests allowed	Latitude	Longitude	MEPLAN zone
1	TaichungFengjia 7WarehouseRoom III	2	24.1784	120.6448	74
2	Dein Zimmer+breakfast/for 1 person	1	24.1121	120.6808	168
3	Taichung Fengjia - DODO travel	2	24.1740	120.6479	75
4	Cozy Suite with Sunshine & Herb	2	24.1529	120.6593	107
5	台中逢甲-Kitty room Taichung Fengjia	2	24.1784	120.6448	74

Table 4-13 Examples of Airbnb data and the matching model zone

The listings from Airbnb are checked against listings from other sources to remove the duplicates with the same method outlined before and number of guests allowed per night is aggregated on a zonal basis. As mentioned in 3.2.2.3, the occupancy rate for Airbnb accommodation is needed to complete the estimation. From a conference held in Taipei (Executive Yuan, 2015) the representative of Airbnb stated that the occupancy rate in Taiwan is in the order of 30 to 60 days per year. Therefore, the average occupancy rate is estimated to be 12.3% and the number of guests per night in each zone can be estimated by Equation 3.15 (Table 4-14).

Model zone	Number of guests allowed per night ( $gm_j$ )	Estimated number of guests per night ( $g_j$ )
6	13	1.60
8	6	0.74
36	2	0.25
74	497	61.27
75	503	62.01

Table 4-14 Some zones with the estimated number of Airbnb guests per night

#### 4. Estimation of tourists staying with friends and family:

This group has been estimated based on the data from a yearly survey conducted by Department of Statistics of Feng-Chia University (Lee et al., 2015) where 25.6% of respondents stated they stayed at accommodation establishments and 10% of respondents stated that they stay with friends and family. Based on this ratio, the total number of people staying with friends and family can be calculated.

With the previous estimation of the number of tourists staying in Taichung, it is estimated that a total number of 21,646 tourists stay at tourist accommodation establishments. Table 4-15 below shows some examples at zonal level the aggregated number of guests per night staying at tourist accommodation establishments.

Model zone	Estimated number of guests per night from all sources
1	0.00
2	0.49
3	133.09
4	66.19
5	32.48
137	1965.59
All zones	21,646

Table 4-15 Example of estimated number of tourists staying at accommodation establishments

The Feng-chia survey (Lee et al., 2015) shows that 25.6% of the respondents stated they stayed at accommodation establishments while 10% of the respondents stated they stayed with friends. Therefore, based on Equation 3.16, 8468 tourists are estimated to stay at friends' places when they visit Taichung.

To get the number of tourists staying with friends and family in each zone, the total number of tourists is allocated to each zone based on the zonal population size (Equation 3.17). Table 4-16 below shows some data examples at zonal level the number of tourists staying with friends and family per night.

Model zone	Number of Population ( $p_j$ )	Tourists stay with friends and family ( $gf_j$ )
1	24832	53.39
2	20308	43.66
3	53555	115.14
4	32051	68.91
137	5153	11.08
253	33526	72.08

Table 4-16 Number of tourist staying with friends and family by zone

#### 4.4 Transport model specifications

The transport model is a strategic multi-modal model with 253 zones and is built upon a comprehensive representation of the network in the study area. It has been set up to use stochastic user equilibrium assignment combined with a hierarchical multinomial logic



model for modal split. The modes include cars, bus, walking, cycling, motorcycle and railway.

The basic unit of measurements are: cost in New Taiwan Dollar (NTD), time in minutes, distance in kilometres and capacity in passenger car units (pcu's) on the road. The strategic transport model is a full day model covering 24 hours of traffic which are represented with four time periods on a typical week day.

As described in Chapter 3, the model uses link based congestion factors, which lead to the congested speeds for different types of links by different time periods, estimated by historical data gathered with Google Direction API. Intra-zonal trips are also modelled through a distance-band based approach. For the calibration, again, travel time from Google Direction will be used for comparison with the modelled results which will be presented later in the chapter.

The matrices assigned to the network consist of synthetic matrices of all travel by residents and tourists from the land use model.

#### **4.4.1 Passenger travel demand segments**

We define the mode choice model by firstly defining the passenger travel demand segments (which are called 'flows' in MEPLAN terminology). The passenger travel demand is firstly segmented by five trip purposes which follows the segmentation from the land use model. Secondly, the travel demand is further divided into four time periods to cover 24 hours based on the peak hour periods specified in the Taichung Report 2016. In the Taichung Report 2016, the AM peak period is specified as between 7.00 and 8.59, the inter peak period as between 13.00 and 14.59, the PM peak period as between 17.00 and 18.5, and the evening peak period as between 20.00 and 21.59. As this model intends to model 24-hour traffic flows, the peak periods proposed here include the shoulders of each peak period with the evening peak period stretching beyond evening hours to the dawn time. This is to ensure that the majority of trips departing in each time period are captured in the same time period when they arrive - approximately 30 minutes after the departure time, as reported in the Taichung Report 2016. Therefore, the proposed four time periods are from 06.00 to 9.59 for the AM peak, from 10.00 to 15.59 for the Inter peak, from 16.00 to 19.59 for the PM peak, from 20.00 to 05.59 for the Evening peak. The definition and codes used in the model for travel demand segments are summarised in the following Table 4-17.

	AM 06.00 – 9.59	Interpeak 10.00- 15.59	PM 16.00 - 19.59	Evening 20.00- 05.59
HBW, from trades 111-130	1	6	11	16
HBE, from trades 131-150	2	7	12	17
HBO, from trade 151-170	3	8	13	18
NHB, from trade 171-190	4	9	14	19
NMarket, from trade 201-208 & 211-215	-	-	15	20

Table 4-17 Flow definition by type of activity by time period

The estimation of travel demand has been calculated by converting the trade volumes to flow volumes with different proportions for outward and return journeys. The corresponding proportions of trips made during each time period for each purpose based on the survey results from the Taichung Report 2016 are shown in the tables below.

Flow during AM peak		Flow during Inter peak		Flow during PM peak		Flow during Evening peak		Total
1	76%	6	15%	11	6%	16	4%	100%
2	77%	7	4%	12	17%	17	1%	100%
3	44%	8	24%	13	25%	18	7%	100%
4	81%	9	5%	14	11%	19	3%	100%
	-		-	15	51%	20	49%	100%

Table 4-18 Proportions of flows to activities by departure time period

Flow during AM peak		Flow during Inter peak		Flow during PM peak		Flow during Evening peak		Total
1	3%	6	11%	11	66%	16	20%	100%
2	0%	7	5%	12	79%	17	16%	100%
3	30%	8	28%	13	28%	18	14%	100%
4	13%	9	29%	14	53%	19	6%	100%
	-		-	15	47%	20	53%	100%

Table 4-19 Proportions of flows from activities by departure time period

#### **4.4.2 Transport network**

The transport network used as the base network for this research was built for the project 'Taichung metropolitan area road network planning (version 2)' (2009, CECI). This was provided for this research by THI consultant, a Taiwanese transport and planning consulting firm. The data files were converted from TransCAD to the MEPLAN format. New roads have been added to the network to reflect the changes between 2007 and 2013. Also, nodes along the links, centroids of each zone and access links to the centroids are generated and added to the network. The centroids' locations were determined by observing the settlement pattern on Google Maps. In built-up areas, it is straightforward to determine the location of centroids from Google Maps. However, in more rural areas where there are less obvious settlements shown on Google Maps, data from Foursquare, pinpointed onto the GIS platform showing local shop locations, was used to aid in determining the centroid locations.

The modified network was rigorously tested to make sure no errors existed in the source data and that no errors were introduced during modification. Shortest path tests in GIS were performed from the four zones at the corners of Taichung to one of the zones containing the Feng-chia commercial centre as well as from every zone to that zone. The connectivity between every node is ensured with the shortest path method. Finally, the real route distance and the straight line distance between two nodes was measured in GIS and if the ratio between the two types of distance exceeded 3, which refers to the top 10% of the ratios' distribution and signifies a noticeable difference between the two types of distances, then a modification was made to the network to ensure the network provides reasonable representation of the real road network.

Since the model is intended to model traffic for four different time periods, we have considered the speed variations from one time period to another and adopted the original link types, their codes and characteristics, such as link speed, for carrying AM traffic. The link types from the original network include types listed in Appendix 2.

##### ***4.4.2.1 Congested Link Speed Estimation by Time Period***

As mentioned earlier, the aim of this research is to establish an approach to modelling travel demand by different time periods. Therefore, the model needs to have the capability to represent the variation in congested speeds during each time period. With the method set out in Chapter 3, road types are grouped into nine broad types based on their characteristics. For example, link types 23 and 30, despite containing different

number of lanes and central reservation arrangement, are grouped together since they are both urban roads with median interference and face similar congestion levels. Figure 4-16 shows an example of the routes picked for estimating congested speeds on the urban roads with median interference. The conversion rates by road type and time period were derived and a full set of the rates can be found in Appendix 3.

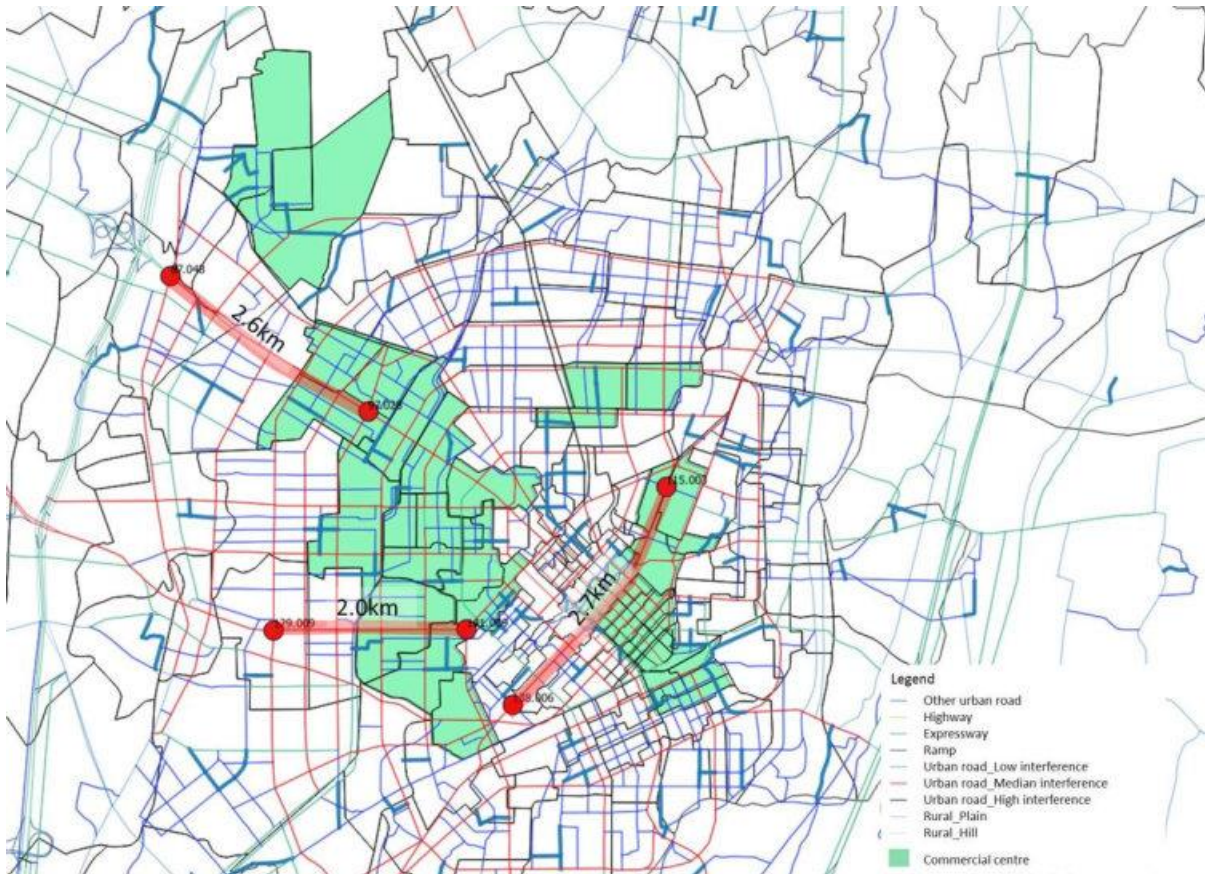


Figure 4-16 Routes for estimating congested speeds on the urban roads with median interference

#### **4.4.2.2 Validation of the congested speed estimation**

We further test the validity of the estimated congested link speed by comparing the modelled results, i.e. the travel time and distance, between some zone pairs with other data via Google Maps Directions API. Three zones are picked because they all have commercial centres within them and are popular with both commuting travellers and as leisure travellers. The routes between each pair all contain travelling along or crossing one of the busiest arterial roads in Taichung and all the feeder roads and local streets between each zone pair also often experience congestion during the peak hours.

Therefore, all three routes are expected to represent typical travel on congested urban roads in Taichung. Table 4-20 shows that the results of travel distance and travel time for each route. The results show good estimation by the method with travel distance errors ranging from -1% to 4% and the travel time error between -16% and 12% for all time periods.

Origin zone	Destination zone	Time period	Modelled		Google Direction (driving)		Distance error	Travel time error
			Distance (km)	Travel time (min)	Distance (km)	Travel time (min)		
74_Feng-chia Precinct	97_New City Hall Precinct	AM	2.37	7.31	2.41	8.15	-1%	-10%
		Inter		8.15		9.10		-10%
		PM		9.07		10.33		-12%
		Eve		7.13		8.48		-16%
74_Feng-chia Precinct	137_Taichung Railway Station	AM	7.28	18.46	6.98	19.42	4%	-5%
		Inter		21.21		22.79		-7%
		PM		24.30		25.18		-4%
		Eve		18.10		19.62		-8%
97_New City Hall Precinct	137_Taichung Railway Station	AM	5.56	15.03	5.61	13.44	-1%	12%
		Inter		17.39		16.74		4%
		PM		20.68		18.78		10%
		Eve		14.75		13.91		6%

Table 4-20 Comparison of travel time and distance between model results and Google Direction data

#### 4.4.2.3 Intrazonal road networks

The supplementary intra-zonal transport networks have been developed according to the specifications in Chapter 3. Firstly, nine standard distance ranges are defined for road travel. The number of the distance ranges are specified in line with common distance categorisation used in metropolitan scale models such as those of London and South East Regional Model (LASER, see Jin, Williams and Shahkarami, 2002) and the Greater Beijing Strategic Transport Model (Deng, 2015). Since the travel speeds on roads in the built up areas are usually significantly different from the more sparsely populated suburban and rural roads, two types of distance ranges are defined (Table 4-21). Secondly, the number of distance ranges is defined for each zone. This is done through the GIS, where the zone boundaries and the radii of built-up areas and entire zones are measured. The radii are then used to determine how many range links will be

needed in each zone for both built-up and rural conditions. Finally, the link speeds for each band for two different conditions are defined (Table 4-22).

Band	Distance Range (km)		Average Length (km)	Roads within built-up area	Roads outside built-up area
	From	Up to			
1	0.0	1.0	0.334	4001	4011
2	1.0	2.0	1.125	4002	4012
3	2.0	5.0	2.800	4003	4013
4	5.0	10.0	6.375	4004	4014
5	10.0	15.0	11.250	4005	4015
6	15.0	20.0	16.100	4006	4016
7	20.0	25.0	21.150	4007	4017
8	25.0	50.0	36.000	4008	4018
9	50.00	Infinity	75.000	4009	4019

Table 4-21 Definition of intrazonal distance bands and link types

Band	Roads within built-up area	Roads outside built-up area
1	4	4
2	8	8
3	12	12
4	16	16
5	20	20
6	24	24
7	28	28
8	32	32
9	36	36

Table 4-22 Link speeds by intrazonal band (km/h)

#### **4.4.2.4 Rail and metro networks for future planning scenarios**

At the time of writing this dissertation, Taichung has one surface railway lying in the east of the city linking the urban area (shown in pink in Figure 4-17 below) and areas outside the urban area. The railway line is going to be upgraded to an elevated medium-capacity metro line (Red Line) serving more passengers between the urban area and the regional centre in the north. Also, five existing stations are being elevated to allow easy ground



movement which is now hindered by this surface railway line. The metro line is scheduled to open in 2017.

Also, another metro line (Green line) running through the urban area from the north east to the south west is under construction and scheduled to open in 2020.

Further away from the urban area in the west of the city, there is a regional railway line (light blue) linking the subcentres which show slow but steady population growth over the last decades and bus services from the urban area provide good connection to the subcentres in the west. Lastly, a new railway line (dark blue) will be added in the north of Taichung to facilitate the growth in the area. Since the future scenario year is set in 2041, it is assumed that these railway lines or metro lines will be operational by that year and therefore they are coded in the transport network separately from the road links.

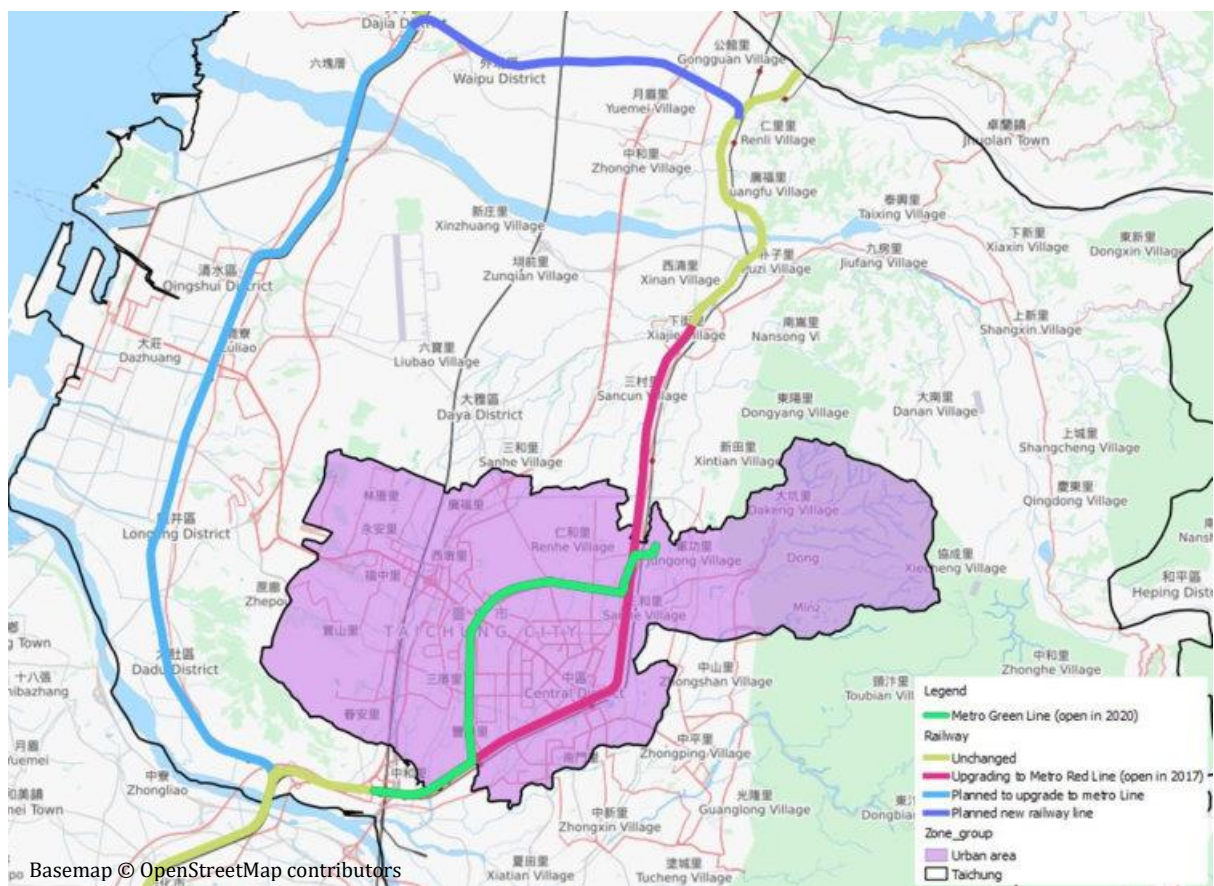


Figure 4-17 Public transport provisions in Taichung

#### 4.4.2.5 Travel costs and tariffs

The operating costs for cars and motorcycles are derived from the report titled 'The Survey of Vehicle Operation Cost and Application for Economic Benefits Evaluation of Transportation Projects' (Ministry of Transportation and Communications [MOTC],

2011). The values in question are coefficients, which relate operating costs to average link speed. The figures, which are based on the 2011 prices in the report, have been converted to 2013 prices. As for bus tariffs, since the city government encourages people to use buses, the fare is mostly free in the urban areas. Therefore, the fare is coded as zero in the model. The metro tariff for the future scenarios is assumed to be a similar level to the current Taipei Metro tariff. The Taipei Metro tariff was collected in May 2016 and used as model input for the future scenarios for the case study area in Taichung.

#### **4.4.2.6 Values of time**

Another set of parameters used in the model are those relating to value of time. In this model, they have been input as fixed values which are documented in DORTS (2016). The data includes value of time for different time periods and by trip purposes. These data were derived based on two government reports ‘The Survey of Vehicle Operation Cost and Application for Economic Benefits Evaluation of Transportation Projects’ (MOTC, 2011) and ‘The Transportation Demand Forecasting Model Version IV of Taipei Rapid Transit System’ (DORTS, 2011). Table 4-23 summarises the values used by each travel demand segment defined in the previous section.

	Travel Demand Segment _ Inverse of Value of Time			
	AM	Inter	PM	Evening
HBW	1_0.3115	6_0.3390	11_0.3185	16_0.3390
HBE	2_0.8000	7_0.6757	12_0.9009	17_0.6757
HBO	3_0.8000	8_0.8475	13_0.6849	18_0.8475
NHB	4_0.6369	9_0.8475	14_0.7634	19_0.8475
NMarket	-	-	15_0.7634	20_0.8475

Table 4-23 Value of time by travel demand segment

#### **4.4.3 Definition of transport modes**

In MEPLAN, the definition of transport mode can be divided into two stages. Firstly, the main modes are defined, such as car or bus, which are called user modes. Secondly, the user modes may include distinct travel stages using different network modes. For instance, travel on the main mode ‘Bus’ may involve network modes such as: walk access to a bus stop, waiting at the bus stop, boarding the bus, riding the bus etc. For ease of model implementation, the intrazonal modes are defined separately from the interzonal modes and are subdivided by distance band. Appendix 4 contains the definitions for the



user modes and network modes in addition to the flow utilising the user modes and the links used by the network modes for four time periods.

#### **4.5 Model Calibration**

The model calibration involves calibration for trips of HBW, HBE, HBO, NHB and night market trips based on a comprehensive representation of the multimodal transport network as presented above. Since the detailed modal choice data for each O-D pair is not available, it is not feasible to carry out parameter estimation for the modal choice model through formal procedures such as maximum likelihood maximisation. Therefore, aggregate observed modal choice patterns for HBW, HBE, HBO and NHB trips, reported in DORTS (2016), are used for calibration which will be presented in 4.5.1. Similarly, for the night market trips' calibration, only aggregate data in certain dimensions is available such as the modal split and number of people travelling to Feng-Chia commercial centre. The process and results will be presented in 4.5.2.

Overall, two sets of parameters have been estimated in the calibration process. These are the trade concentration parameters in the land use model and the user mode specific constants in the transport model. The calibration is run iteratively between land use and transport model until the model results match well with the aforementioned datasets.

##### **4.5.1 Calibrating spatial distribution and modal split for conventional activities**

As mentioned above, the data sources used for calibrating the residents' HBW, HBE, HBO, NHB trips are datasets reported in DORTS (2016). These datasets are (1) trip length distribution by trip purpose, (2) travel time by mode and (3) trip purpose by mode. The DORTS data is based on surveys conducted between 2014 and 2015 and is considered suitable for calibrating the 2013 existing case since no major transport network changes during these years and population growth is minimal.

Estimation of the parameters in the land use model begins by giving an initial value of 0.05 to all trade concentration parameters of each household type by each trade. Secondly, user mode specific constants in the transport model were given the initial value of 0 for bus. Various combinations of all these values were tested in the calibration process where several iterative runs were required until the model produces data close to the observed data subject to the constraints, the attraction totals, specified in 4.2. Concentration parameters for these four trips are presented in Table 4-24. The full set of estimated user mode specific constants are attached in Appendix 5.

Table 4-25 presents the distribution of the trip length by trip purpose. Overall, the model can reproduce reasonably well the observed trip length distribution for each trip purpose. Figure 4-18 and Figure 4-21 present the modal shares for each trip purpose. Again, the model can reproduce reasonably well the modal shares across different trip purposes. More calibration and validation may be desirable at a finer level of geographical detail and with various time periods when new survey data emerges in the future.

HBW	HBE	HBO	NHB
0.024	0.028	0.035	0.028

Table 4-24 Concentration parameters by type

	HBW		HBE		HBO		NHB	
Distance	Observed	Modelled	Observed	Modelled	Observed	Modelled	Observed	Modelled
0~1 km	17%	16%	31%	30%	32%	32%	22%	23%
1~2 km	7%	9%	12%	12%	17%	18%	11%	10%
2~3 km	9%	12%	11%	10%	13%	13%	11%	10%
3~4 km	9%	8%	7%	7%	8%	8%	9%	8%
4~5 km	9%	8%	6%	7%	6%	7%	7%	8%
5~6 km	7%	7%	5%	6%	5%	5%	6%	6%
6~7 km	7%	6%	4%	5%	4%	4%	5%	6%
7~8 km	5%	5%	4%	4%	3%	3%	3%	4%
8~9 km	4%	4%	3%	3%	2%	2%	4%	4%
9~10 km	3%	3%	2%	3%	1%	2%	3%	3%
10~15 km	10%	11%	7%	8%	5%	4%	8%	10%
15~20 km	5%	5%	4%	3%	2%	1%	5%	5%
20~25 km	3%	3%	2%	1%	1%	0%	3%	3%
25~30 km	2%	2%	1%	1%	0%	0%	1%	1%
30~40 km	1%	1%	1%	0%	0%	0%	1%	1%
40~50 km	0%	0%	0%	0%	0%	0%	0%	0%
>50 km	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Table 4-25 Distance band distribution by trip purpose

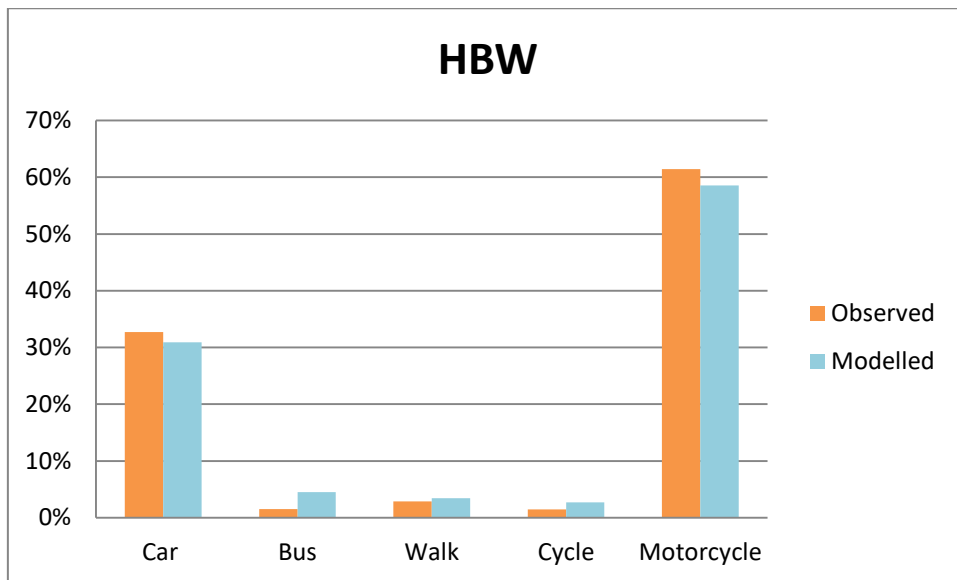


Figure 4-18 Modal share for HBW

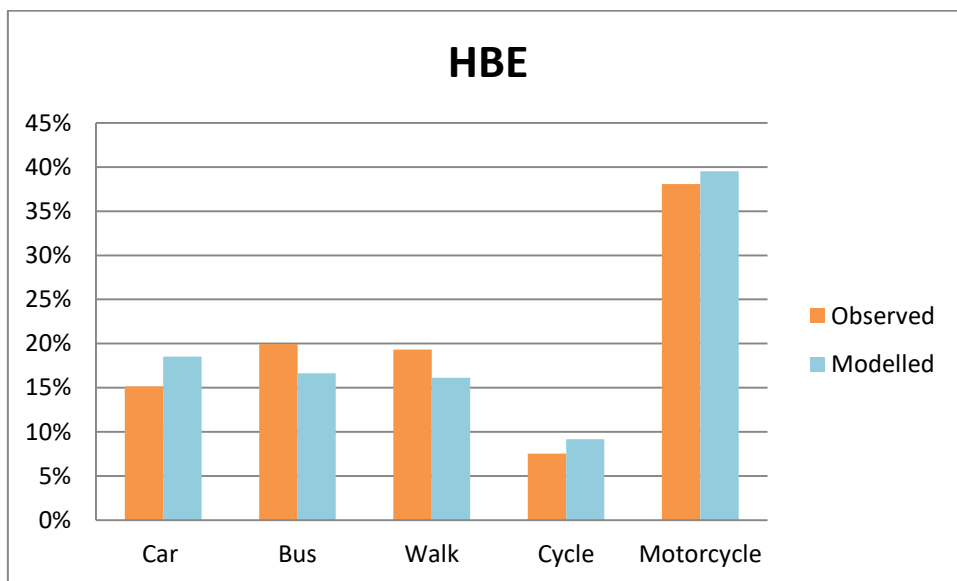


Figure 4-19 Modal share for HBE

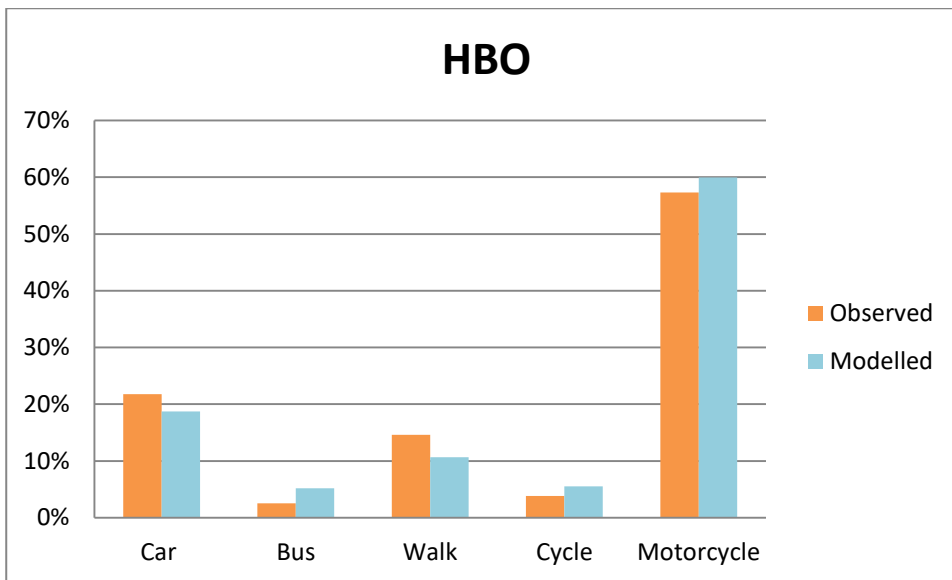


Figure 4-20 Modal share for HBO

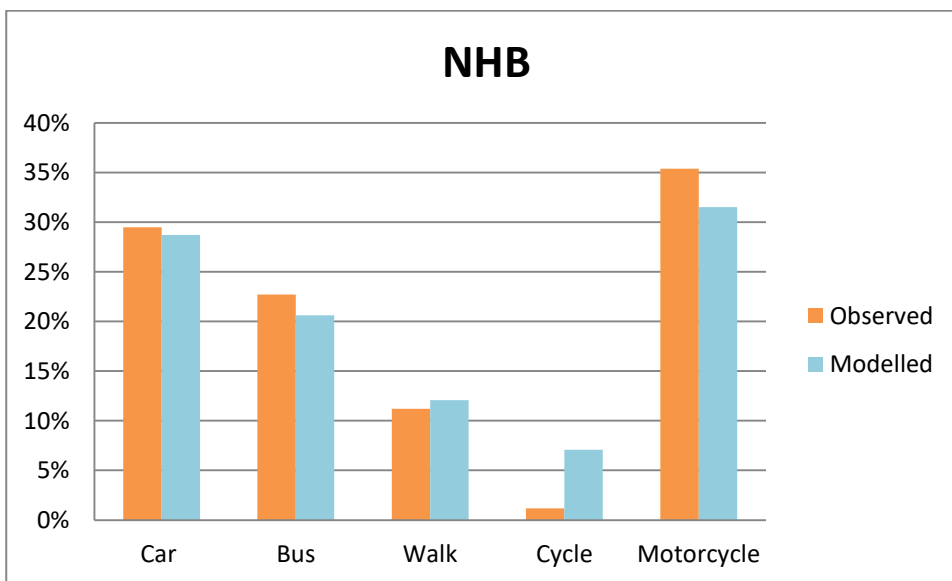


Figure 4-21 Modal share for NHB

#### 4.5.2 Calibrating spatial distribution and modal split for night market activities

As set out in section 4.3.2 Night market activities for Taichung residents, the calibration involves estimating two types of model parameters, the concentration parameter and the user mode specific constant, and a share of residents' demand for the night market activities from home. The procedure and the parameters have already been presented in section 4.3.2 so Table 4-26 below shows a comparison of the modelled results and the

observed data based on Feng-chia survey. The home based and non-home based visitors are grouped back together based on age segmentation for comparison purpose.

Home-based night market visitors	Non-home based night market visitors	Observed data		Modelled result		Error (%)
Age 00-14	Students	403	68%	452	67%	12%
Age 15-19		2016		2149		7%
Age 20-24		6720		6603		-2%
Age 25-29	Employees	2419	32%	2514	33%	4%
Age 30-34		941		975		4%
Age 35-39		538		582		8%
Age 40-59		269		324		20%
Age 60+	-	134		66		-51%
Total	-	13440	100%	13666	100%	2%

Table 4-26 Calibration results of residents' spatial distribution and modal split for night market activities

For the distribution of tourists' trips, it is deduced from the survey (Lee et al., 2015; DORTS, 2016) that 7560 visitors to Feng-chia are tourists. Among them 5460 stay in accommodation establishments in Taichung while 2100 stay at friend's place. Therefore, the concentration parameters for tourists are chosen such that the modelled results can fit well with these two values. As with conventional activities, the calibration of spatial distribution and modal split is done iteratively so modal split from Feng-chia survey is used for this purpose. Table 4-27 and Figure 4-22 summarise the parameters and show the comparison between observed data and modelled results. The modelled results in general fit well. However, this is only based on a survey of one of many commercial centres in Taichung therefore it is desirable to conduct further calibration if more data becomes available.

Night markets visitor type	Concentration parameter	Observed data	Modelled result	Error (%)
Tourists staying at accommodation establishments	0.040	5460	5379	-1.48%
Tourists staying at friends' places	0.040	2100	2105	0.23%

Table 4-27 Calibration results of tourists' spatial distribution and modal split

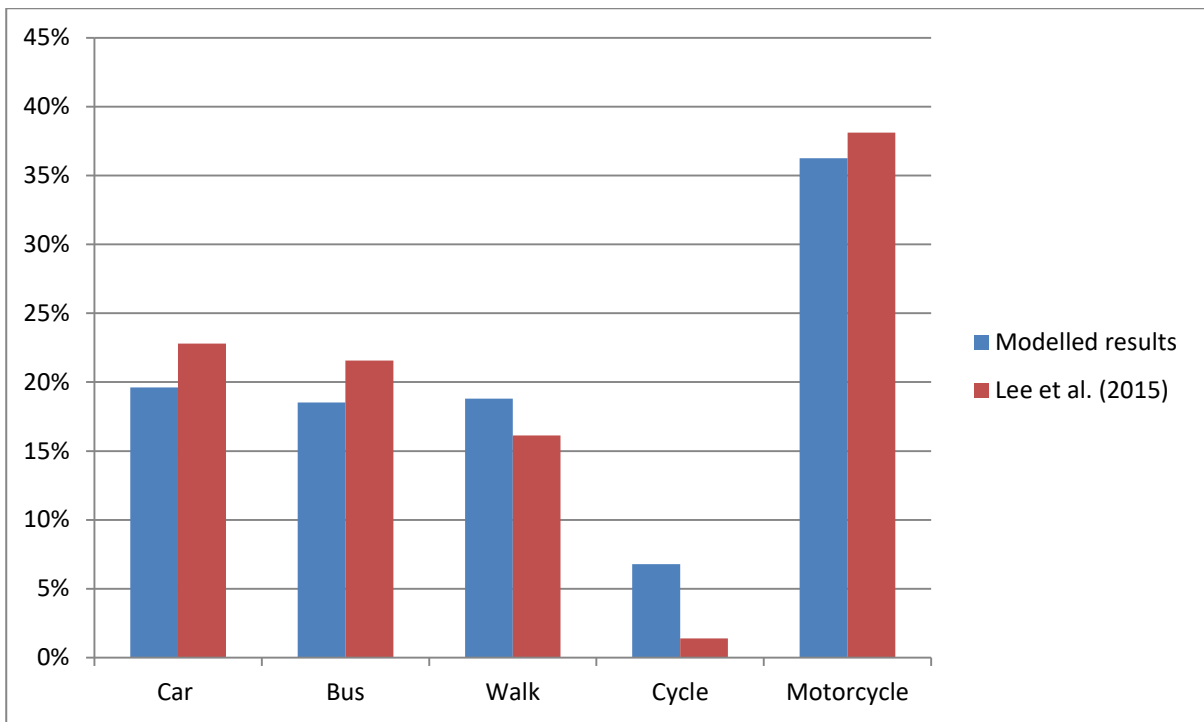


Figure 4-22 Calibration results of tourists' modal split

#### 4.6 Model Implementation

The methodology is implemented on the MEPLAN package on a personal computer with 8Gb of RAM. Each model run takes around 25 – 30 minutes. It was envisaged that the proposed model structure with new components to fill the gap regarding discretionary travel may potentially overload the previous model structure. Therefore, initially, the proposed model structure was tested with a test run wherein only two O-D pairs were included. Once the test run suggested the proposed model structure could perform well, more O-D pairs were added as the model inputs.

As stated previously, all the data with geo-spatial information has been allocated to each model zone with the aid of GIS. QGIS, an open-source desktop GIS application, is employed for this research. Additionally, the analysis tools in QGIS helped accomplish data analysis tasks such as identifying the total number of comments in each zone.

In addition to data extraction from the websites as detailed in section 4.2.3 Web data extraction, the model calibration was also done with R since some outcomes of the model, such as the user modes between each O-D pair by activity types, contain more than 6 million rows and the data of this size cannot be easily manipulated in excel. Therefore, R scripts played a key role in facilitating the process of calibration which involves

aggregating the raw model outcomes into a format which can be compared with the observed data. The model calibration took about 7 months.

## Chapter 5 SCENARIO TESTS

Following model calibration, verification and validation in the preceding chapter, we apply the model in scenario tests represent both a continuation of the current trends and radical masterplanning scenarios. The purpose of the scenario tests is to demonstrate the capabilities of the new modelling methodology in dealing with a wide range of transport and land use planning measures that can be tested. In line with local planning horizons, we set the scenario test period to be 2013-2041. Such scenario tests can be further expanded and refined in practice, for instance in collaboration with local government agencies in future work.

The definition of the scenarios consists broadly two categories of inputs. The first category is exogenous inputs that are common to all scenario tests - for our purposes here they are primarily projected demographic changes over the test period; in line with the current trends of development, we assume economic indicators such as the unit prices of goods, services and travel remain constant in real terms (although these can be varied in scenario variations). The second category is scenario specific inputs as summarised below.

We structure the scenario specific inputs in three sets: the first is for a Business As Usual (BAU) scenario which represents the land use and transport developments without radical interventions in transport investments or land use masterplanning that are beyond what have already been considered in the existing documents; the second is for an urban densification and regeneration scenario [Regeneration Area Shui-nan Airport Site (RaSnAS)]; the third is for regional subcentre developments that aim to decentralise population and economic activity [Regional Subcentre (RS)].

The main purpose of the BAU scenario is to provide a benchmark for exploring future land use and transport planning scenarios. DORTS (2016), Taichung household travel survey and review and development of travel demand model, predicts that the total number of households will grow by 11.2% and residents by 3.8% in 2041 with a trend for people moving to the suburban area. The BAU test is presented in Section 5.2.

The purpose of the RaSnAS scenario is to explore the potential of a radical densification and regeneration proposal which happens to be near the Feng-chia night market. In recent years, Taichung has seen an old airport site being decommissioned and as a result the land has been released as a potential urban regeneration site. The regeneration plan



is to include functions such as commerce, research and innovation, education, culture centres in the site in the hope that site will breathe new life into the urban core of Taichung. This test is presented in Section 5.3.

The purpose of the RS scenario is to explore another radical masterplanning initiative by the government to close the development gap between the existing Taichung urban core and the rest of Taichung. Four regional subcentres are envisaged to enhance economic growth in the wider metropolitan area. Among the infrastructure investment measures are upgrading the existing railway lines in the east of the city and constructing a new line linking up the east and the west part of Taichung. This test is presented in Section 5.4.

The scenario test results will be presented in terms of pairwise comparisons which help digest the vast arrays of model outputs. First the main travel indicators of the BAU scenario for 2041 are compared with those of the Base Year (2013) to establish a benchmark trajectory of growth and changes. Secondly the RaSnAS scenario is compared with BAU. Thirdly the RS scenario is compared with BAU. The findings and insights from the comparisons will be considered in Chapter 6.

## **5.1 Exogenous Demographic Assumptions**

From Figure 5-1 and Figure 5-2 below, we can see the official projected changes in number of households and population in Taichung between 2013 and 2041, such as provided by DORTS (2016). Most of the area will experience increase in the number of households. However, the numbers of people do not increase in line with the household trend. This is because of the shrinking household size experienced in Taichung. Overall, the total number of household in 2041 is expected to grow by 11.2% and the number of residents 3.8% in relation to year 2013. For this research, several assumptions have been made in relation to the land use change input. Firstly, the total number of households and residents remain the same in all future land use scenarios however the distribution of households and residents varies from one to another. Secondly, people relocate to this area from other modelled zones in proportion to the population size of the zone, i.e., the larger the population size of a zone, the more households and residents will relocate from that zone to the airport site or a regional subcentres. Thirdly, the total number of jobs, students and tourists in RaSnAS 2041 scenario remains the same as the BAU 2041. Similar to the assumption made for population relocation, the jobs, students and tourists will be redistributed based on the number of jobs, students and tourists in the original zone. Lastly, for the RS 2041 scenario, it is assumed that the annual growth rates in the four

subcentres are double the rates assumed in the BAU 2041 scenario. Detailed land use assumption from all future scenarios in relation to the existing data can be found in Appendix 6.

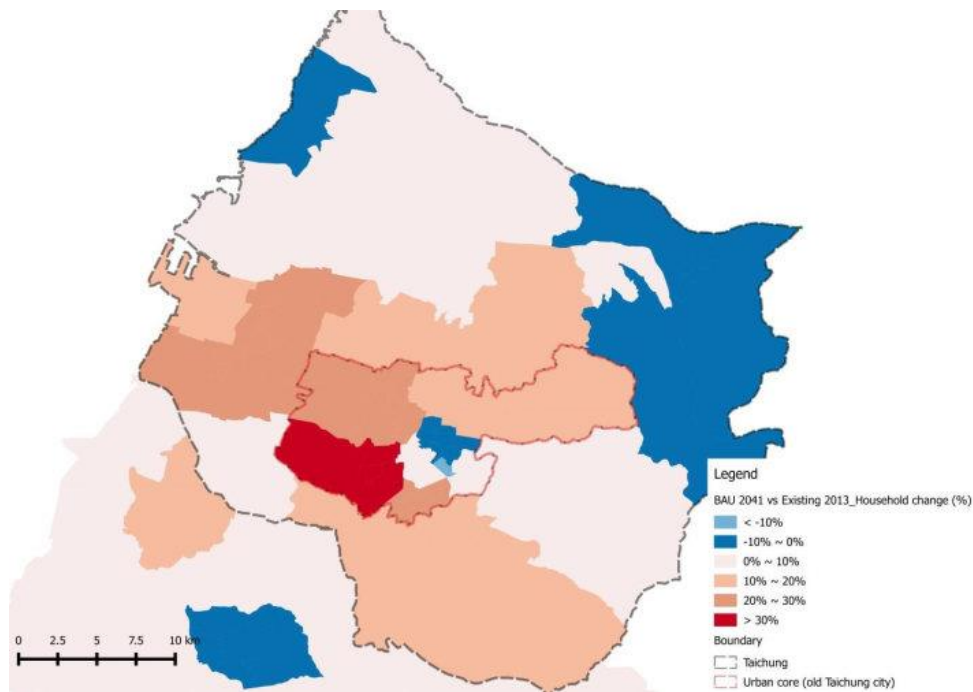


Figure 5-1 Projected change in households 2013- 2041 in Taichung

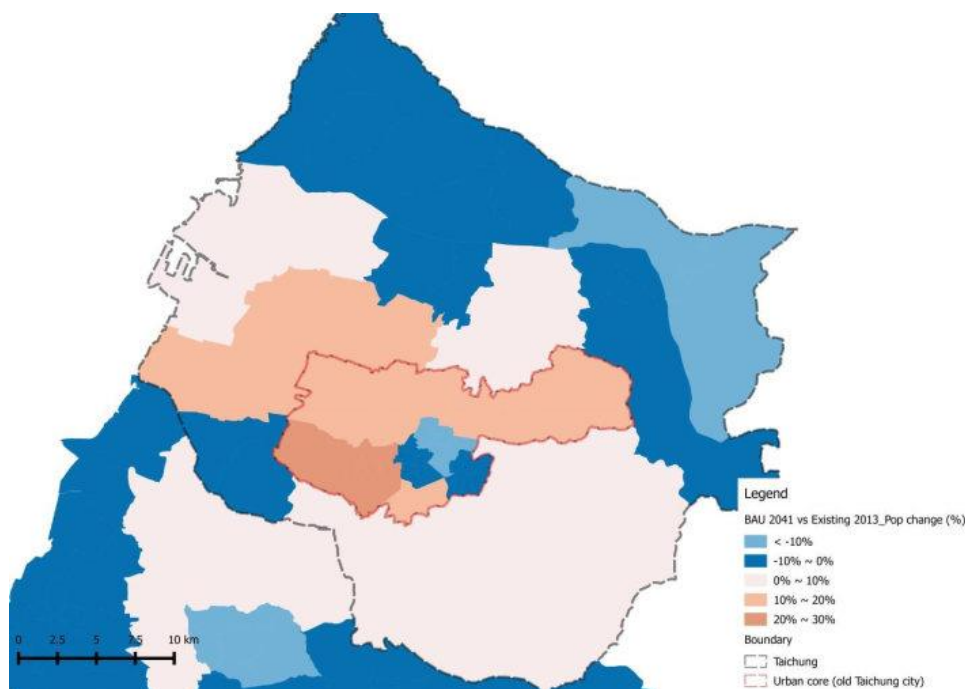


Figure 5-2 Projected change in population 2013- 2041 in Taichung

## **5.2 The BAU Scenario**

### **5.2.1 Travel demand**

Table 5-1 summarises the travel demand by trip purpose by mode for Existing 2013. Different trip purposes have different mode share and trip length distribution. The average trip length of going to night time activities is 3.16 km which is the shortest. The results also show that the night time activities trips consist of 8% of the total trip which is a significant amount. Overall, the average journey lengths and mode share patterns conform well to the observed data, and thus form a reasonably good starting point for examining future year policy scenario tests. Table 5-2 shows the travel demand by time period by mode. The result show that PM period has the highest share of flow volume among the four time periods as opposed to the AM period. Also, there are more flows during the evening period than the interpeak period. This is in line with the expectation that the night time activities in Taichung play a role in generating traffic at night.

Existing 2013						
Activity	Mode	Ave. distance	Ave. cost	Ave. time	FlowVol.	Trip-km
HBW	Total	7.02	21.83	27.61	5,266,516	36,968,856
	Car	9.39	46.96	28.30	1,627,100	15,286,458
	Bus	8.88	0.00	57.24	236,281	2,099,021
	Walk	1.90	0.00	27.00	179,000	339,636
	Cycle	6.01	0.00	33.53	141,735	851,738
	Mcycle	5.97	12.51	24.75	3,082,400	18,392,003
HBE	Total	4.75	8.57	28.86	3,005,913	14,277,215
	Car	4.09	23.31	21.48	557,185	2,276,674
	Bus	7.97	0.00	55.46	500,455	3,987,262
	Walk	1.75	0.00	25.20	484,740	849,910
	Cycle	5.38	0.00	30.36	275,732	1,482,846
	Mcycle	4.78	10.75	22.26	1,187,800	5,680,523
HBO	Total	3.78	7.91	22.21	2,721,768	10,275,080
	Car	4.50	19.05	22.67	508,715	2,290,860
	Bus	6.28	0.00	49.32	141,287	886,604
	Walk	1.77	0.00	25.43	290,227	514,071
	Cycle	4.10	0.00	25.06	149,439	613,063
	Mcycle	3.66	7.26	18.89	1,632,100	5,970,483
NHB	Total	5.76	10.33	31.40	1,154,716	6,650,570
	Car	6.19	24.03	24.71	331,652	2,053,735
	Bus	7.93	0.00	54.65	238,142	1,888,197
	Walk	1.82	0.00	26.02	139,465	253,762
	Cycle	5.29	0.00	30.28	81,612	431,452
	Mcycle	5.56	10.88	24.58	363,845	2,023,424
NMT	Total	3.16	4.80	23.83	1,015,642	3,204,716
	Car	3.30	14.46	20.46	195,958	646,833
	Bus	5.60	0.00	48.03	197,502	1,105,118
	Walk	1.20	0.00	18.32	198,115	238,176
	Cycle	2.91	0.00	19.60	67,533	196,466
	Mcycle	2.86	5.72	16.14	356,534	1,018,123
Total		5.42	13.60	26.82	13,164,554	71,376,438

Table 5-1 Travel demand by trip purpose by mode under Existing 2013 scenario

Existing 2013						
Time period	Mode	Ave. distance	Ave. cost	Ave. time	FlowVol.	Trip-km
AM	Total	5.62	14.31	26.22	4,779,889	26,849,178
	Car	7.39	35.90	25.36	1,165,500	8,613,418
	Bus	7.89	0.00	52.81	450,455	3,555,140
	Walk	1.74	0.00	24.99	423,340	736,768
	Cycle	4.98	0.00	28.74	238,995	1,189,170
	Mcycle	5.10	10.61	21.81	2,501,600	12,754,683
IP	Total	5.35	13.64	26.20	1,720,102	9,209,810
	Car	6.95	33.18	25.40	425,253	2,954,379
	Bus	7.77	0.00	54.51	132,955	1,032,604
	Walk	1.80	0.00	25.92	144,557	260,586
	Cycle	4.96	0.00	28.81	85,491	424,252
	Mcycle	4.87	10.03	22.34	931,846	4,537,989
PM	Total	5.43	13.52	28.45	4,922,550	26,747,527
	Car	6.99	34.30	26.25	1,215,700	8,499,457
	Bus	7.55	0.00	56.55	527,631	3,985,397
	Walk	1.73	0.00	24.97	527,733	915,284
	Cycle	5.32	0.00	30.25	305,386	1,625,874
	Mcycle	5.00	10.60	23.82	2,346,100	11,721,514
Eve	Total	4.92	11.84	24.48	1,740,766	8,562,312
	Car	6.01	29.55	22.85	413,756	2,484,627
	Bus	6.87	0.00	48.76	202,573	1,392,650
	Walk	1.44	0.00	21.36	195,877	282,851
	Cycle	3.90	0.00	24.32	86,120	336,180
	Mcycle	4.83	9.95	20.18	842,440	4,066,004
Total		5.42	13.60	26.82	13,163,307	71,368,827

Table 5-2 Travel demand by time period by mode under Existing 2013 scenario

Table 5-3 shows the travel demand by trip purpose by mode for BAU 2041 and Table 5-4 shows the comparison between Existing 2013 and BAU 2041 scenario. The rail mode is not shown in the comparison table since this is a new mode. The results show that the overall flow volume will increase by 2% under the BAU 2041 scenario, however, for the night time activities the trip volume drops by 18%. This is because the model factors in the aging population in Taiwan and assumes that night time trips are mostly made by young people.

Table 5-5 and Table 5-6 show the travel demand by time periods. The evening trips drop by 3% which is caused by the drop in night time activities. However, since there are other types of trips made during the evening so the drop is not as sharp.

BAU 2041						
Activity	Mode	Ave. distance	Ave. cost	Ave. time	FlowVol.	Trip-km
HBW	Total	7.08	22.06	27.50	5,446,265	38,561,028
	Car	9.54	47.63	28.26	1,670,500	15,936,704
	Bus	8.90	0.00	57.05	245,149	2,181,498
	Walk	1.96	0.00	27.31	184,835	361,996
	Cycle	6.06	0.00	33.51	147,216	892,436
	Mcycle	5.96	12.49	24.78	3,155,700	18,799,388
	Rail	9.08	26.63	8.89	42,864	389,007
HBE	Total	4.81	8.71	28.79	3,103,381	14,913,854
	Car	4.13	23.55	21.49	564,851	2,332,296
	Bus	7.99	0.00	55.33	516,195	4,123,101
	Walk	1.80	0.00	25.47	498,201	897,241
	Cycle	5.42	0.00	30.36	284,324	1,541,171
	Mcycle	4.78	10.75	22.31	1,213,400	5,799,931
	Rail	8.33	25.35	9.22	26,410	220,115
HBO	Total	3.83	8.04	22.28	2,806,984	10,740,915
	Car	4.56	19.31	22.74	518,404	2,364,302
	Bus	6.32	0.00	49.24	147,337	931,048
	Walk	1.82	0.00	25.73	299,166	545,669
	Cycle	4.16	0.00	25.15	154,864	644,056
	Mcycle	3.67	7.29	19.00	1,673,000	6,147,589
	Rail	7.62	24.56	8.88	14,213	108,250
NHB	Total	5.82	10.47	31.32	1,192,963	6,939,428
	Car	6.26	24.30	24.74	337,181	2,110,975
	Bus	7.94	0.00	54.47	246,604	1,958,929
	Walk	1.88	0.00	26.35	143,238	268,771
	Cycle	5.34	0.00	30.33	84,338	450,559
	Mcycle	5.56	10.89	24.66	371,875	2,068,933
	Rail	8.35	25.54	8.99	9,726	81,262
NMT	Total	3.23	4.83	23.92	832,300	2,692,197
	Car	3.35	14.78	20.68	154,742	517,966
	Bus	5.93	0.00	48.70	162,217	961,442
	Walk	1.20	0.00	18.09	164,959	198,311
	Cycle	2.93	0.00	19.59	55,533	162,773
	Mcycle	2.84	5.70	16.14	291,944	829,394
	Rail	7.68	24.72	8.84	2,906	22,311
Total		5.52	13.92	26.82	13,381,892	73,847,422

Table 5-3 Travel demand by trip purpose by mode under BAU 2041 scenario

BAU 2041						
Activity	Mode	Ave. distance %	Ave. cost %	Ave. time %	FlowVol. %	Trip-km %
HBW	Total	1%	1%	0%	3%	4%
	Car	2%	1%	0%	3%	4%
	Bus	0%	0%	0%	4%	4%
	Walk	3%	0%	1%	3%	7%
	Cycle	1%	0%	0%	4%	5%
	Mcycle	0%	0%	0%	2%	2%
HBE	Total	1%	2%	0%	3%	4%
	Car	1%	1%	0%	1%	2%
	Bus	0%	0%	0%	3%	3%
	Walk	3%	0%	1%	3%	6%
	Cycle	1%	0%	0%	3%	4%
	Mcycle	0%	0%	0%	2%	2%
HBO	Total	1%	2%	0%	3%	5%
	Car	1%	1%	0%	2%	3%
	Bus	1%	0%	0%	4%	5%
	Walk	3%	0%	1%	3%	6%
	Cycle	1%	0%	0%	4%	5%
	Mcycle	0%	1%	1%	3%	3%
NHB	Total	1%	1%	0%	3%	4%
	Car	1%	1%	0%	2%	3%
	Bus	0%	0%	0%	4%	4%
	Walk	3%	0%	1%	3%	6%
	Cycle	1%	0%	0%	3%	4%
	Mcycle	0%	0%	0%	2%	2%
NMT	Total	3%	1%	0%	-18%	-16%
	Car	1%	2%	1%	-21%	-20%
	Bus	6%	0%	1%	-18%	-13%
	Walk	0%	0%	-1%	-17%	-17%
	Cycle	1%	0%	0%	-18%	-17%
	Mcycle	-1%	0%	0%	-18%	-19%
Total		2%	2%	0%	2%	3%

Table 5-4 Travel demand comparison by trip purpose by mode between BAU 2041 and Existing 2013

BAU 2041						
Time period	Mode	Ave. distance	Ave. cost	Ave. time	FlowVol.	Trip-km
AM	Total	5.68	14.50	26.14	4,937,716	28,032,612
	Car	7.50	36.40	25.36	1,190,400	8,923,238
	Bus	7.92	0.00	52.66	465,395	3,687,996
	Walk	1.79	0.00	25.25	435,009	778,070
	Cycle	5.02	0.00	28.75	246,499	1,236,673
	Mcycle	5.10	10.62	21.85	2,558,400	13,046,100
	Rail	8.58	25.74	8.86	42,013	360,535
IP	Total	5.41	13.81	26.18	1,776,411	9,611,707
	Car	7.06	33.71	25.43	434,549	3,067,119
	Bus	7.78	0.00	54.34	138,063	1,074,473
	Walk	1.86	0.00	26.23	148,961	276,630
	Cycle	5.02	0.00	28.85	88,615	444,721
	Mcycle	4.87	10.04	22.40	954,719	4,651,104
	Rail	8.49	25.80	9.00	11,504	97,662
PM	Total	5.54	13.87	28.50	4,978,757	27,587,899
	Car	7.19	35.24	26.38	1,220,700	8,771,413
	Bus	7.68	0.00	56.76	526,747	4,047,009
	Walk	1.80	0.00	25.44	524,696	945,151
	Cycle	5.43	0.00	30.50	309,214	1,678,371
	Mcycle	5.02	10.67	23.98	2,367,000	11,886,719
	Rail	8.53	25.98	9.26	30,400	259,237
Eve	Total	5.10	12.46	24.54	1,687,727	8,607,201
	Car	6.25	30.89	23.10	399,588	2,497,741
	Bus	7.19	0.00	49.27	187,246	1,346,079
	Walk	1.50	0.00	21.75	181,691	272,077
	Cycle	4.04	0.00	24.79	81,901	331,111
	Mcycle	4.92	10.15	20.44	825,098	4,056,687
	Rail	8.48	25.58	8.77	12,202	103,506
Total		5.52	13.92	26.82	13,380,610	73,839,420

Table 5-5 Travel demand by time period by mode under BAU 2041 scenario



BAU 2041						
Time period	Mode	Ave. distance %	Ave. cost %	Ave. time %	FlowVol. %	Trip-km %
AM	Total	1%	1%	0%	3%	4%
	Car	1%	1%	0%	2%	4%
	Bus	0%	0%	0%	3%	4%
	Walk	3%	0%	1%	3%	6%
	Cycle	1%	0%	0%	3%	4%
	Mcycle	0%	0%	0%	2%	2%
IP	Total	1%	1%	0%	3%	4%
	Car	2%	2%	0%	2%	4%
	Bus	0%	0%	0%	4%	4%
	Walk	3%	0%	1%	3%	6%
	Cycle	1%	0%	0%	4%	5%
	Mcycle	0%	0%	0%	2%	2%
PM	Total	2%	3%	0%	1%	3%
	Car	3%	3%	0%	0%	3%
	Bus	2%	0%	0%	0%	2%
	Walk	4%	0%	2%	-1%	3%
	Cycle	2%	0%	1%	1%	3%
	Mcycle	1%	1%	1%	1%	1%
Eve	Total	4%	5%	0%	-3%	1%
	Car	4%	5%	1%	-3%	1%
	Bus	5%	0%	1%	-8%	-3%
	Walk	4%	0%	2%	-7%	-4%
	Cycle	4%	0%	2%	-5%	-2%
	Mcycle	2%	2%	1%	-2%	0%
Total		2%	2%	0%	2%	3%

Table 5-6 Travel demand comparison by time period by mode between BAU 2041 and Existing 2013

### **5.2.2 Link traffic volumes under BAU 2041**

This section looks at hourly traffic volumes of each inter-zonal link under BAU 2041 scenario.

Figure 5-3 to Figure 5-6 below show the capacity ratio for each link for each peak hour for the BAU 2041. Links that are over-capacity are shown in the thickest line with the links of over 50% capacity and still below the capacity highlighted in lighter hue. The rest of the links are loaded however are well under-capacity. In general, AM and PM peak hours have more over-capacity links than other two peak hours. As expected, the congested links concentrate in urban area in Taichung. One of the subcentre in the north, and Zhang-hua city in the south are also expected to contain over-capacity links. Some links are congested in the AM peak hour but not so in the PM peak hour with the opposite direction of links exhibit an otherwise pattern. During the Evening peak very few links are over-capacity and they are only slight over the capacity. During the Inter peak hour there are no over-capacity links.

The following two figures look at the results from different angle. Figure 5-7 highlight the links which is over-capacity and whether this occurs during AM or PM peak hour. Figure 5-8 shows the links which is between 50% and 100% capacity and whether this happens during the AM or PM peak hour. The results also show that all links take the maximum flow either during AM or PM peak hours.

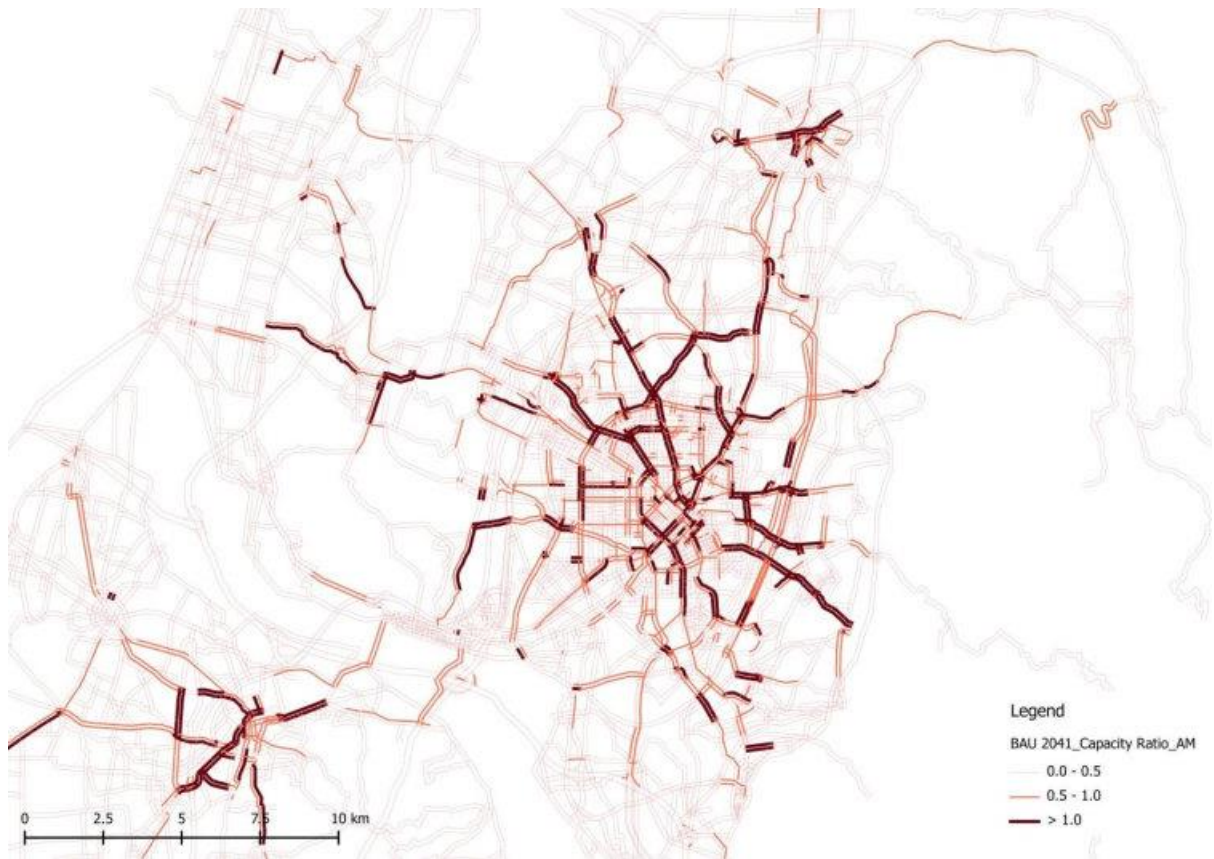


Figure 5-3 Link load/capacity ratio in AM peak hour for BAU 2041

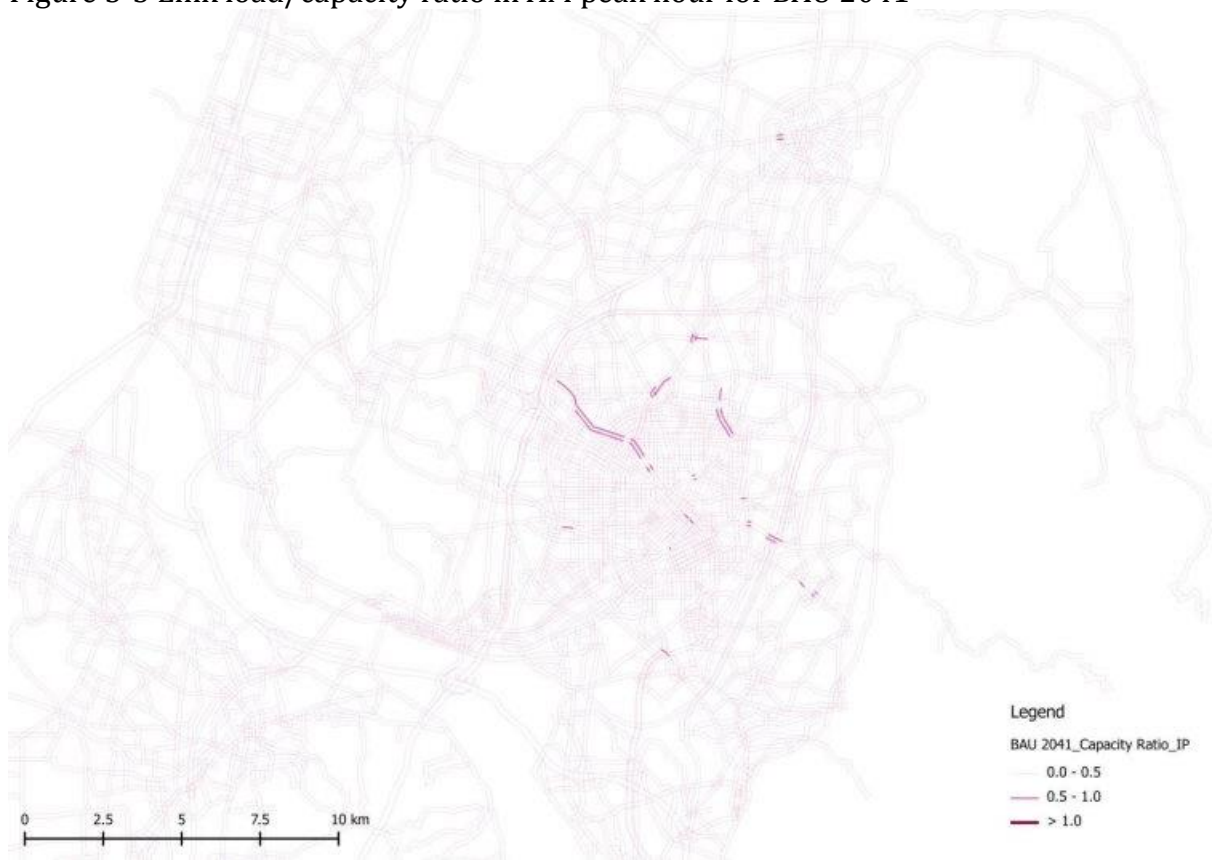


Figure 5-4 Link load/capacity ratio in Interpeak hour for BAU 2041

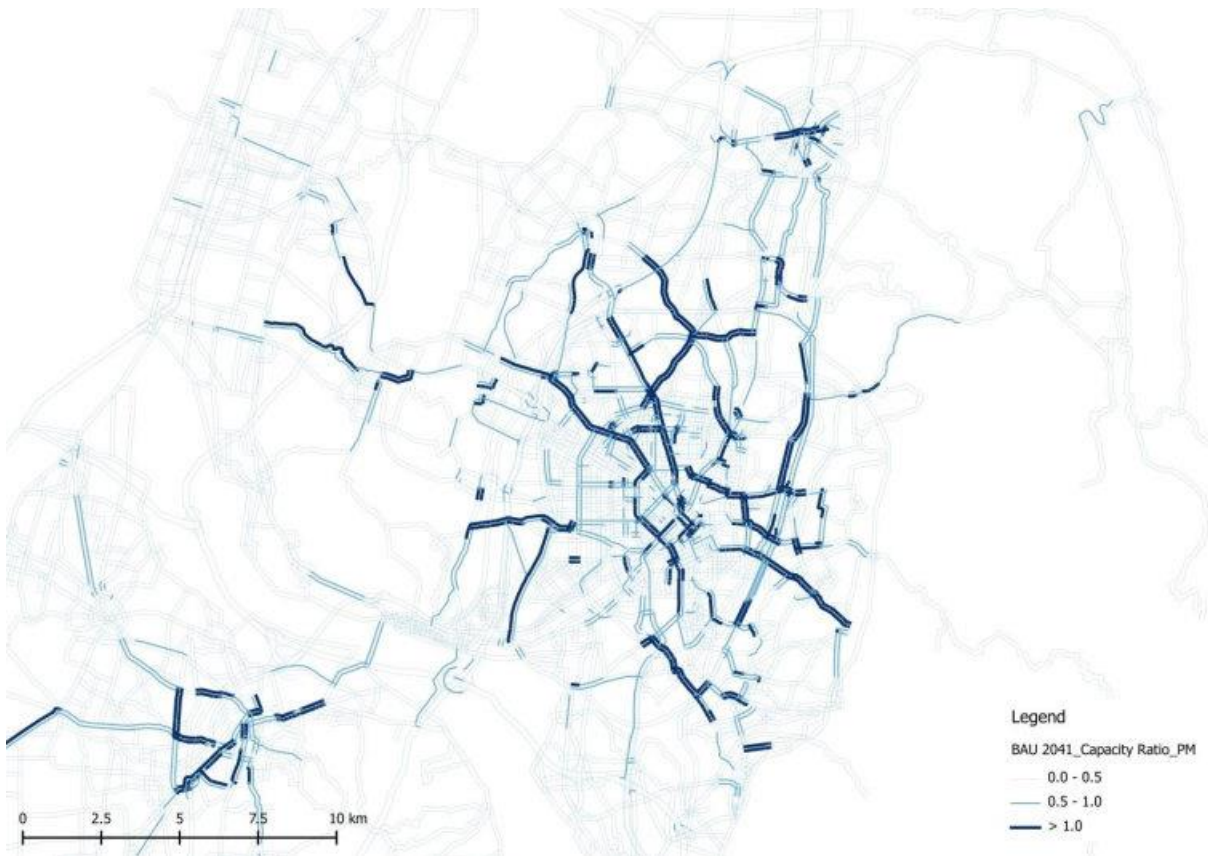


Figure 5-5 Link load/capacity ratio in PM peak hour for BAU 2041

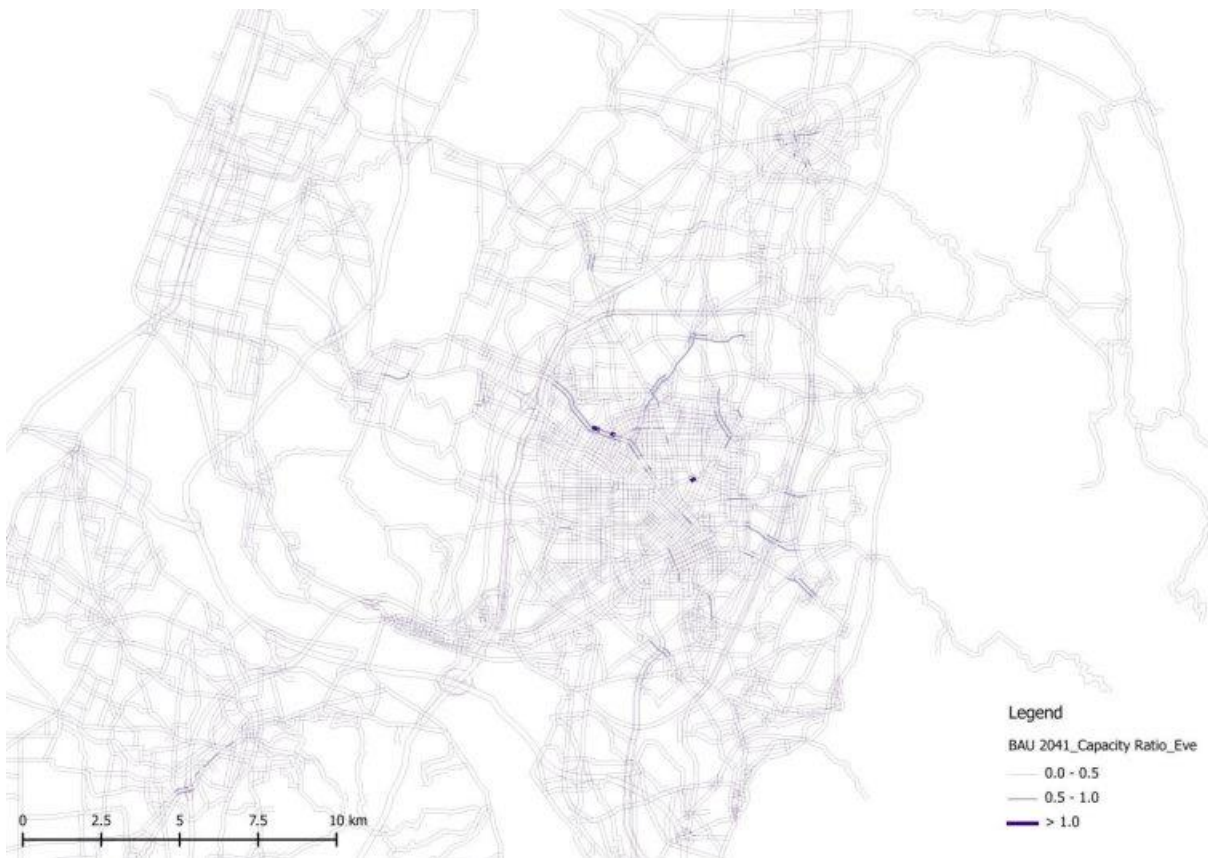


Figure 5-6 Link load/capacity ratio in Evening peak hour for BAU 2041



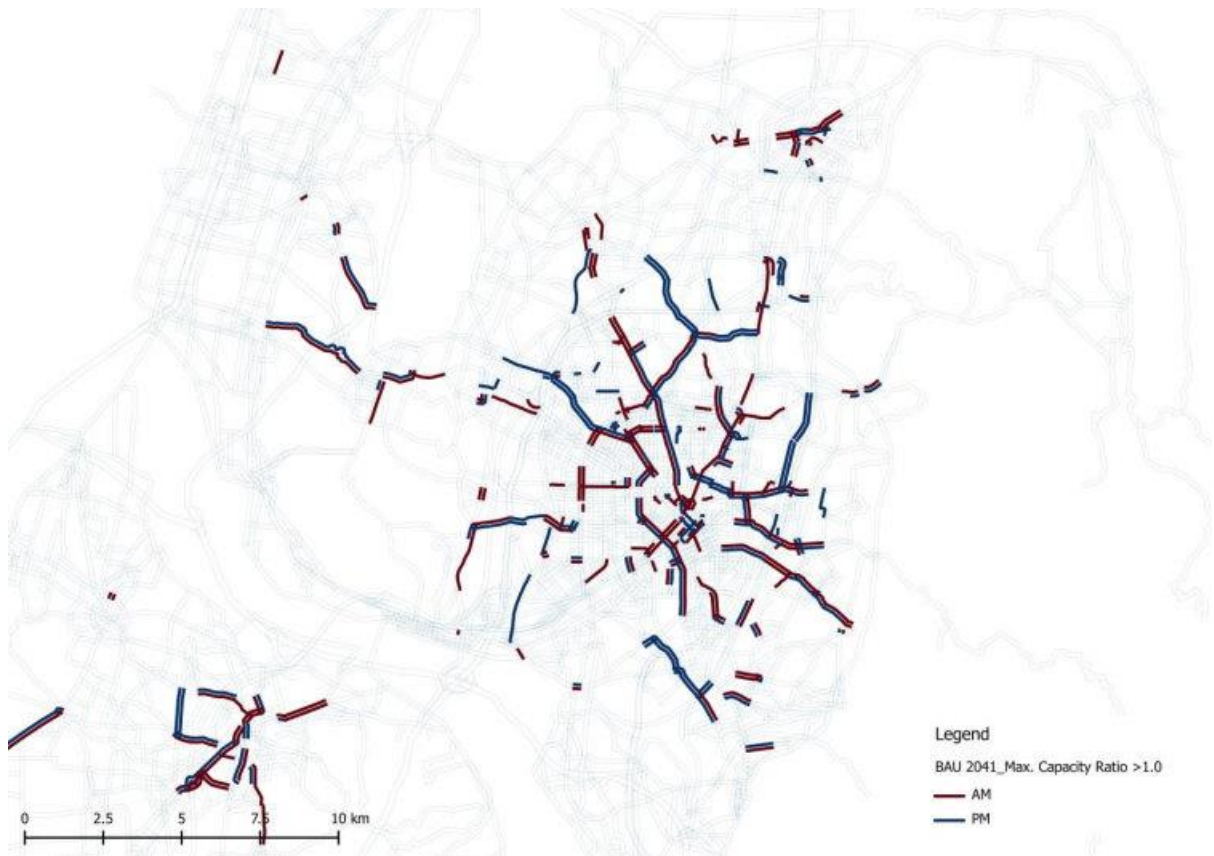


Figure 5-7 Maximum link load/capacity ratio > 1 by peak hour for BAU 2041



Figure 5-8 Maximum link load/capacity ratio between 0.5 and 1 by peak hour for BAU 2041

### 5.2.3 Link traffic volumes comparison between BAU 2041 and Existing 2013

Figure 5-9 shows the flow change between Existing 2013 and BAU 2041. The ratio is the maximum hourly for each link under BAU 2041 scenario and Existing 2013 case. It shows most of the links will experience increase in maximum hourly flows. However, some links experience more change than others. Figure 5-10 to Figure 5-13 show the 4 period flows under BAU 2041 scenario when the links experience increases in flows from existing situation to BAU 2041.

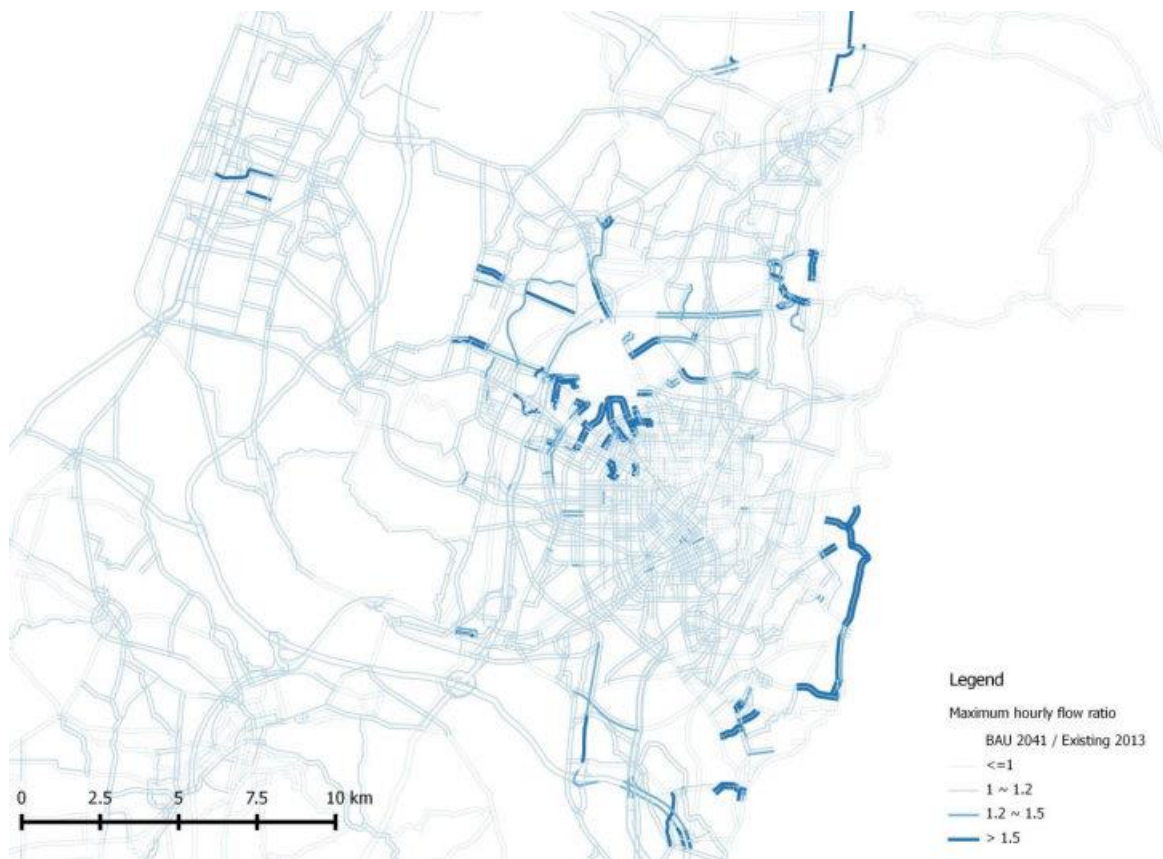


Figure 5-9 Maximum hourly flow ratio between BAU 2041 and Existing 2013 scenario

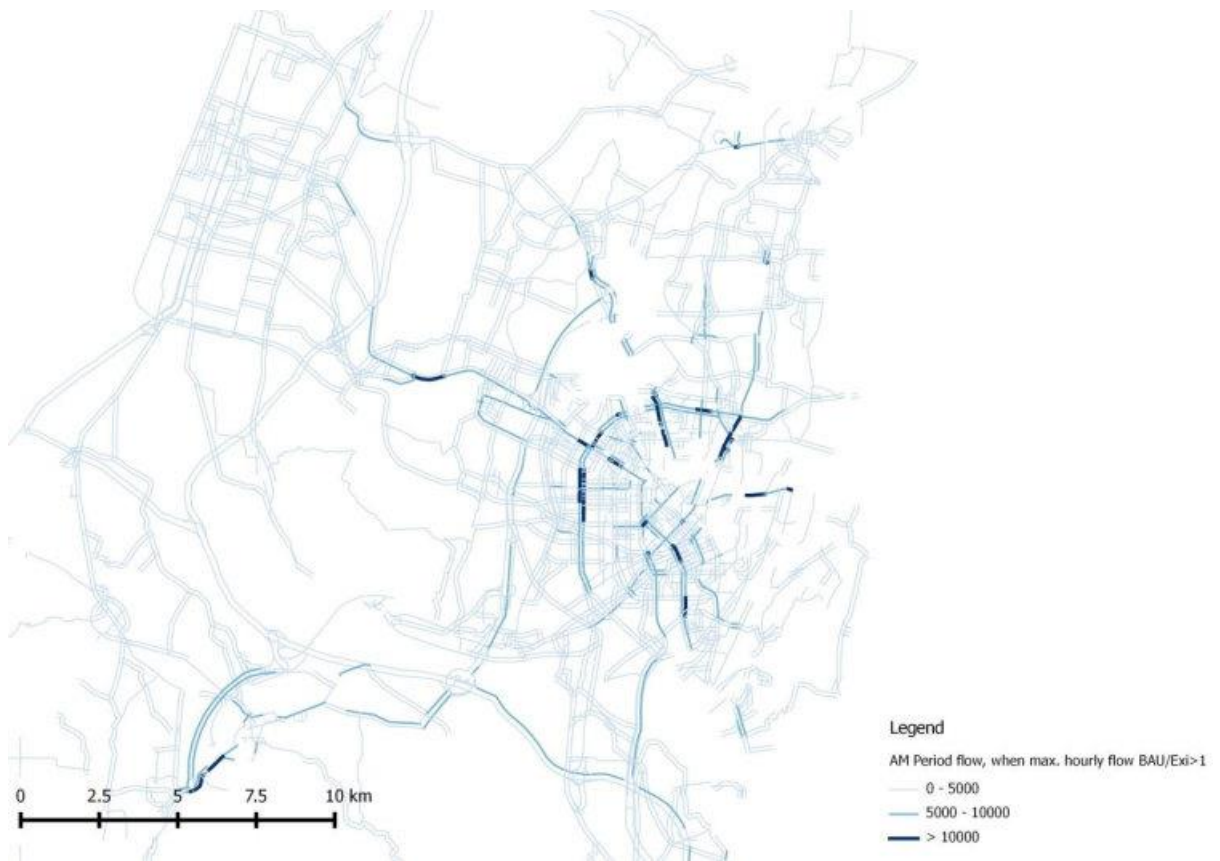


Figure 5-10 AM period flow when the ratio is larger than 1



Figure 5-11 Interpeak period flow when the ratio is larger than 1



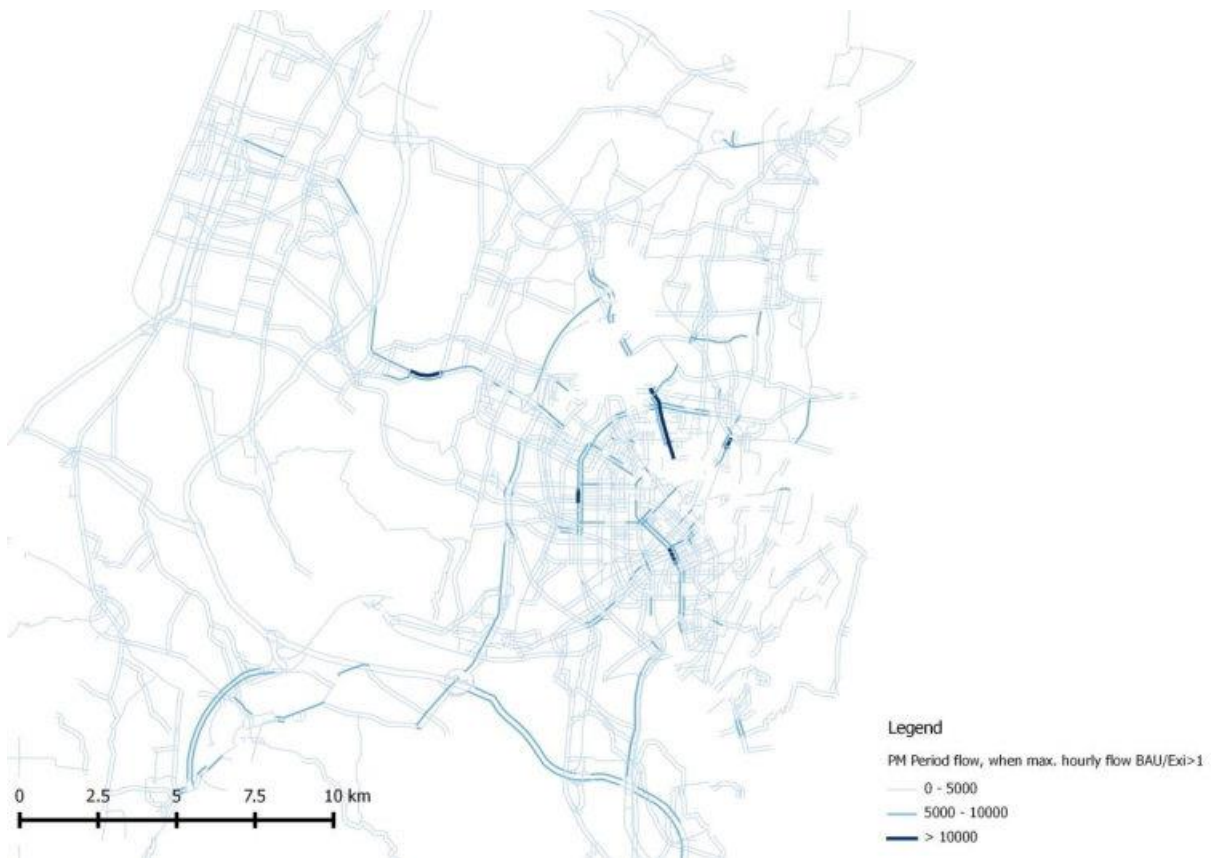


Figure 5-12 PM period flow when the ratio is larger than 1



Figure 5-13 Evening period flow when the ratio is larger than 1



To gauge if a link has been used evenly among all period of times, an index of entropy has been used. The index is defined as

$$\text{Entropy} = \sum_i (P_i * \ln(1/P_i))$$

Where  $P_i$  is the share of traffic volumes on time period  $i$

If the value of entropy is small, this means the link flow differ from time period to time period to a large degree. If, for a link, the share of flows among four time periods are equal, i.e.  $P = 25\%$  for all time periods, then the entropy for the link is estimated to be 1.3863 by the equation. Figure 5-14 below show the individual entropy for each link under two scenarios. The third dimension is introduced here being the all day flows on a link and is in proportion to the size of the bubble. In general, the larger the all day traffic on a link is, the larger the entropy is for that link and this is true for both scenarios, hence, the large sized bubbles on the top right of the figure.

The averaged entropy for all links under Existing 2013 scenario is 1.2134 and under BAU 2041 scenario it is 1.2120. The decrease in the entropy confirms with the expectation that Taichung continues to suburbanise if no major land use changes occur in the city.

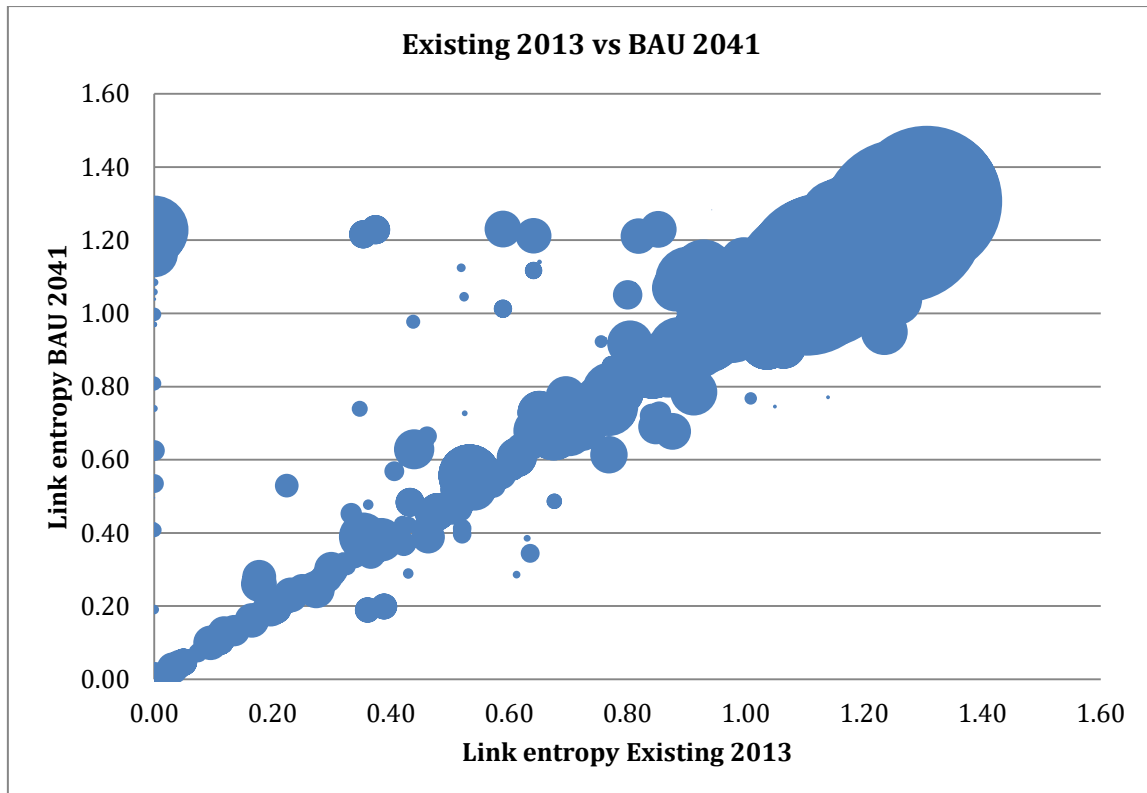


Figure 5-14 Link entropy between Existing 2013 and BAU 2041 scenario

### 5.3 The RaSnAS Scenario

Figure 5-15 illustrates the location of the Shui-nan airport regeneration site in Taichung. The site is located west of the urban core and expected to grow both in terms of number of households and population size. The site is also located next the Feng-chia precinct so the results will be presented to illustrate the impact this site has on Feng-chia precinct as well as the rest of the study area. Table 5-7 summarise the land use schedule for the development of the airport site which is derived from the planning report (Taichung Transportation Bureau, 2014). As mentioned in the previous section, the increase in all the land use changes listed in the table is assumed to prompt a redistribution of land use factors within Taichung in the long term.

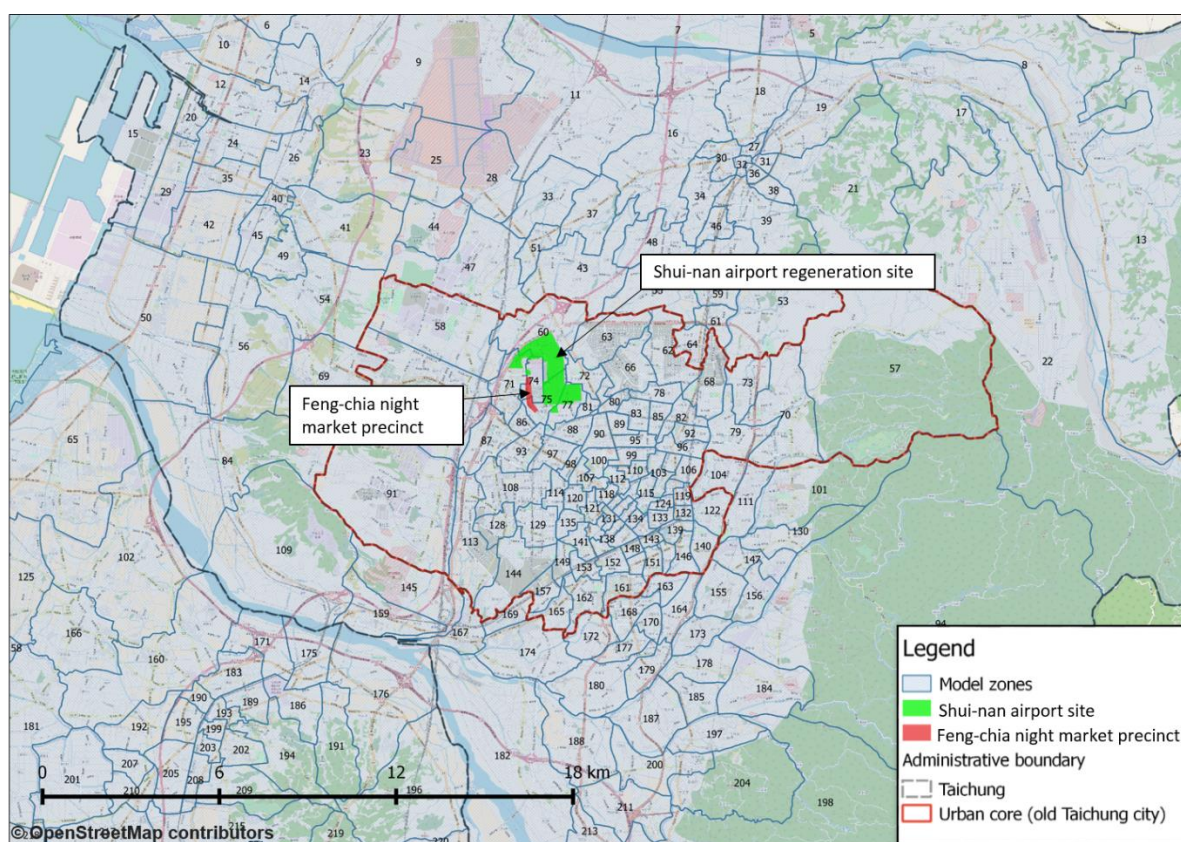


Figure 5-15 Location of Shui-nan airport regeneration site and Feng-chia precinct in Taichung

Type	Number
Household	10,690
Population	26,939
Employment	82,627
Student	21,000
Tourist	12,752

Table 5-7 Land use change in the airport

### **5.3.1 Travel demand**

Table 5-8 shows the comparison between BAU 2041 and RaSnAs 2041 by trip purpose by mode. The results show that the overall flow volume by trip purpose will stay the same under the BAU 2041 scenario. The trip length in night time trips will decrease under the RaSnAs 2041 scenario except for the trips made on foot. The trip length for HBO and NHB trips will increase. These changes in trip length are as the result of the airport site possesses high level of attractiveness for discretionary trips. Table 5-9 shows the travel demand comparison by time periods by mode. The overall flows for each time period stays the same.

RaSnAS 2041						
Activity	Mode	Ave. distance %	Ave. cost %	Ave. time %	FlowVol. %	Trip-km %
HBW	Total	1%	1%	1%	0%	1%
	Car	1%	1%	1%	-1%	1%
	Bus	0%	0%	0%	2%	2%
	Walk	4%	0%	1%	1%	5%
	Cycle	1%	0%	0%	1%	2%
	Mcycle	1%	1%	1%	-1%	0%
	Rail	1%	0%	2%	0%	1%
HBE	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	-1%	0%
	Bus	0%	0%	0%	1%	1%
	Walk	1%	0%	0%	0%	1%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	-1%	0%	0%	6%	5%
HBO	Total	4%	3%	2%	0%	4%
	Car	4%	3%	1%	0%	4%
	Bus	4%	0%	1%	5%	9%
	Walk	5%	0%	1%	0%	5%
	Cycle	4%	0%	2%	1%	6%
	Mcycle	4%	4%	3%	-1%	3%
	Rail	4%	0%	3%	0%	4%
NHB	Total	4%	3%	2%	-1%	4%
	Car	4%	4%	1%	-2%	3%
	Bus	4%	0%	1%	3%	7%
	Walk	5%	0%	1%	-1%	4%
	Cycle	4%	0%	2%	0%	4%
	Mcycle	4%	3%	3%	-1%	2%
	Rail	3%	0%	3%	-2%	2%
NMT	Total	-2%	-2%	-1%	0%	-2%
	Car	-2%	0%	0%	-1%	-2%
	Bus	-3%	0%	-2%	1%	-2%
	Walk	4%	0%	0%	2%	5%
	Cycle	-1%	0%	-2%	0%	0%
	Mcycle	-1%	-1%	0%	-1%	-2%
	Rail	-2%	-1%	1%	-1%	-2%
Total		2%	1%	1%	0%	1%

Table 5-8 Travel demand comparison by trip purpose by mode between RaSnAS 2041 and BAU 2041

RaSnAS 2041						
Time period	Mode	Ave. distance %	Ave. cost %	Ave. time %	FlowVol. %	Trip-km %
AM	Total	2%	1%	1%	0%	1%
	Car	1%	1%	1%	-1%	1%
	Bus	1%	0%	0%	2%	3%
	Walk	3%	0%	0%	0%	3%
	Cycle	2%	0%	1%	1%	2%
	Mcycle	2%	2%	2%	-1%	1%
	Rail	1%	0%	1%	3%	4%
IP	Total	2%	2%	1%	0%	2%
	Car	2%	2%	1%	-1%	1%
	Bus	2%	0%	0%	3%	5%
	Walk	4%	0%	1%	0%	4%
	Cycle	3%	0%	1%	1%	4%
	Mcycle	2%	2%	2%	-1%	1%
	Rail	2%	0%	2%	0%	2%
PM	Total	1%	1%	1%	0%	1%
	Car	2%	2%	0%	0%	1%
	Bus	0%	0%	0%	1%	2%
	Walk	3%	0%	0%	0%	3%
	Cycle	1%	0%	0%	1%	2%
	Mcycle	1%	1%	1%	-1%	0%
	Rail	0%	0%	1%	0%	0%
Eve	Total	1%	1%	1%	0%	1%
	Car	1%	1%	0%	-1%	1%
	Bus	-1%	0%	-1%	1%	1%
	Walk	3%	0%	0%	1%	4%
	Cycle	1%	0%	0%	1%	2%
	Mcycle	1%	1%	1%	-1%	0%
	Rail	1%	0%	1%	2%	3%
Total		2%	1%	1%	0%	1%

Table 5-9 Travel demand comparison by time period by mode between RaSnAS 2041 and BAU 2041

#### ***5.3.1.1 Travel demand relating to airport site and Feng-chia precinct***

Table 5-10 summarises the comparison of results between BAU 2041 and RaSnAS 2041 scenario with the emphasis of airport site and Feng-chia precinct. It shows that the total number of flows of all types going to the airport site will increase in relation to BAU 2041. The increases are the sharpest for NHB trips with the overall passenger trip volume increasing by 413% and trip-km by 500%. The HBO trips to the airport site shows similar pattern however with slightly less intensity. This confirms with the expectation that the regeneration site is relatively more attractive for NHB and HBO activities than other zones because in the model a zone's attractiveness of these two activities is dictated by the number of tertiary jobs in a zone and the airport site in total provides 82,000 tertiary job opportunities. With this notion in mind, the NHB and HBO trips to other areas will decrease meaning that the services in other zones become relatively less attractive compared to the ones provided by the airport site. The closer the area is to the airport site, the more severe the impact will be. For example, in terms of HBO trips, Feng-chia' core area experiences a trip decrease of 15%, the rest of Xi-tun district 11% and the rest of areas 4%. Working trips to the airport site will increase by 244% which is not the greatest change among all types of trips. However, the high trip volume will have a substantial impact on the road near the site.

Most educational trips and night time activity trips to the airport site will also increase. This is because the planned schools and university campuses will draw educational trips to the site. Also, the increased number of students, employees, tourists, and people living at the site will provide the source of demand for the night time activities. The distance travelled to the area will decrease and the only mode with increasing distance travelled is walking. This means with a mixed use area such as the airport site, it is possible to plan the area to reduce the distance travelled for the motorised vehicles. That said, a sensitivity test shows that if the night time activities within the airport were made more attractive, by increasing the attractiveness of the night time activities in line with the new job opportunities within the site, this will, on the contrary, increase the distance travelled of all the modes to the site.



BAU 2041							RaSnAS 2041				RaSnAS 2041_Sensitivity test		
AgDt	AgFi	AgUM	Average distance	Average cost	Average time	Trip volume	Trip-km	Trip volume	Average distance	Trip-km	Trip volume	Average distance	Trip-km
The rest of the study area							37,927,759	-4%	1%	-3%	-4%	1%	-3%
		Car	9.5	47.5	28.2	1,646,100	15,697,786	-3%	1%	-2%	-3%	1%	-2%
		Bus	8.9	0.0	57.2	238,717	2,131,885	-3%	1%	-2%	-3%	1%	-2%
		Walk	1.9	0.0	27.2	180,925	350,103	-4%	2%	-2%	-4%	2%	-2%
		Cycle	6.1	0.0	33.5	143,741	871,212	-3%	1%	-2%	-3%	1%	-2%
		Moyle	6.0	12.5	24.7	3,105,100	18,482,921	-4%	1%	-3%	-4%	1%	-3%
		Rail	9.1	26.7	8.9	41,726	378,747	-6%	1%	-6%	-6%	1%	-6%
Airport site (zone 60 71 75 77)							534,627	244%	0%	245%	244%	0%	245%
		Car	9.7	55.1	34.7	20,186	196,713	290%	3%	241%	230%	3%	241%
		Bus	7.7	0.0	51.3	5,328	40,787	241%	5%	260%	241%	5%	260%
		Walk	3.0	0.0	33.9	3,277	9,918	287%	-6%	262%	287%	-6%	262%
		Cycle	6.0	0.0	32.9	2,882	17,436	232%	-2%	224%	232%	-2%	224%
		Moyle	6.2	13.3	29.5	41,842	260,206	248%	-1%	246%	248%	-1%	246%
		Rail	8.9	25.6	9.6	1,071	9,564	247%	7%	273%	247%	7%	273%
Feng-chia (zone 74 only)							113,533	-7%	-6%	-13%	-7%	-6%	-13%
		Car	10.0	56.5	35.8	4,194	42,058	-6%	-7%	-13%	-6%	-7%	-13%
		Bus	8.0	0.0	52.9	1,103	8,817	-6%	-7%	-12%	-6%	-7%	-12%
		Walk	3.1	0.0	35.9	634	1,978	17%	-14%	1%	17%	-14%	1%
		Cycle	6.3	0.0	34.2	597	3,788	-3%	-10%	-13%	-3%	-10%	-13%
		Moyle	6.4	13.8	30.5	8,751	56,193	-10%	-4%	-13%	-10%	-4%	-13%
		Rail	10.4	25.7	12.8	67	699	-15%	1%	-15%	-15%	1%	-15%
The rest of the study area							14,427,757	-2%	0%	-2%	-2%	0%	-2%
		Car	4.1	23.3	21.3	555,435	2,277,318	-2%	0%	-2%	-2%	0%	-2%
		Bus	8.0	0.0	55.5	494,957	3,962,660	-2%	0%	-1%	-2%	0%	-1%
		Walk	1.8	0.0	25.3	483,715	859,725	-2%	0%	-2%	-2%	0%	-2%
		Cycle	5.4	0.0	30.3	275,098	1,487,225	-2%	0%	-1%	-2%	0%	-1%
		Moyle	4.8	10.7	22.2	1,180,600	5,623,800	-2%	0%	-2%	-2%	0%	-2%
		Rail	8.3	25.4	9.2	25,766	214,245	-1%	-1%	-2%	-1%	-1%	-2%
Airport site (zone 60 71 75 77)							263,042	117%	-6%	104%	117%	-6%	104%
		Car	5.9	40.1	30.5	5,110	30,254	116%	-10%	93%	116%	-10%	93%
		Bus	7.4	0.0	51.4	11,460	84,964	108%	-4%	100%	108%	-4%	100%
		Walk	2.4	0.0	30.2	8,121	19,787	138%	-3%	130%	138%	-3%	130%
		Cycle	5.7	0.0	32.2	5,050	28,913	111%	-6%	98%	111%	-6%	98%
		Moyle	5.2	12.0	26.9	18,347	95,705	107%	-5%	97%	107%	-5%	97%
		Rail	8.9	24.8	11.1	386	3,418	517%	-15%	422%	517%	-15%	422%
Feng-chia (zone 74 only)							226,098	-6%	1%	-5%	-6%	1%	-5%
		Car	5.7	39.7	31.1	4,311	24,764	-6%	0%	-6%	-6%	0%	-6%
		Bus	7.7	0.0	51.6	9,779	75,482	-6%	1%	-5%	-6%	1%	-5%
		Walk	2.8	0.0	32.4	6,368	17,735	-5%	-1%	-6%	-5%	-1%	-6%
		Cycle	6.0	0.0	32.5	4,180	25,050	-6%	0%	-6%	-6%	0%	-6%
		Moyle	5.6	12.7	28.3	14,493	80,600	-6%	1%	-5%	-6%	1%	-5%
		Rail	9.5	24.3	12.5	260	2,467	-7%	1%	-6%	-7%	1%	-6%
The rest of the study area							10,547,992	-5%	2%	-2%	-5%	2%	-2%
		Car	4.5	19.2	22.6	512,828	2,331,549	-3%	2%	-1%	-3%	2%	-1%
		Bus	6.3	0.0	49.3	143,566	908,334	-3%	3%	0%	-3%	3%	0%
		Walk	1.8	0.0	25.6	293,424	530,072	-5%	2%	-3%	-5%	2%	-3%
		Cycle	4.1	0.0	25.1	151,816	629,696	-4%	2%	-2%	-4%	2%	-2%
		Moyle	3.7	7.3	18.9	1,648,400	6,042,870	-5%	2%	-3%	-5%	2%	-3%
		Rail	7.6	24.6	8.9	13,869	105,602	-8%	2%	-5%	-8%	2%	-5%
Airport site (zone 60 71 75 77)							162,484	329%	20%	413%	329%	20%	413%
		Car	5.9	31.7	31.2	4,699	27,620	355%	22%	453%	355%	22%	453%
		Bus	6.0	0.0	45.5	3,190	19,076	364%	19%	454%	364%	19%	454%
		Walk	2.7	0.0	30.2	4,887	13,126	328%	4%	346%	328%	4%	346%
		Cycle	4.7	0.0	26.6	2,571	12,009	348%	17%	422%	348%	17%	422%
		Moyle	4.2	8.7	23.8	20,757	88,055	315%	21%	401%	315%	21%	401%
		Rail	7.6	23.8	9.7	327	2,496	336%	17%	412%	336%	17%	412%
Feng-chia (zone 74 only)							30,350	-15%	-14%	-27%	-15%	-14%	-27%
		Car	5.9	31.8	32.0	879	5,144	-10%	-18%	-26%	-10%	-18%	-26%
		Bus	6.2	0.0	47.0	586	3,639	-16%	-13%	-27%	-16%	-13%	-27%
		Walk	2.8	0.0	32.3	857	2,375	12%	-18%	-8%	12%	-18%	-8%
		Cycle	4.9	0.0	27.7	481	2,360	-13%	-15%	-26%	-13%	-15%	-26%
		Moyle	4.3	8.8	24.7	3,861	16,662	-22%	-10%	-30%	-22%	-10%	-30%
		Rail	9.0	23.9	12.7	19	170	-38%	2%	-36%	-38%	2%	-36%
The rest of the study area							6,820,065	-6%	3%	-4%	-6%	3%	-4%
		Car	6.2	24.2	24.6	333,490	2,083,151	-6%	2%	-3%	-6%	2%	-3%
		Bus	8.0	0.0	54.6	240,876	1,918,648	-5%	3%	-2%	-5%	3%	-2%
		Walk	1.9	0.0	26.2	140,676	261,152	-8%	3%	-5%	-8%	3%	-5%
		Cycle	5.3	0.0	30.3	82,681	441,293	-6%	3%	-3%	-6%	3%	-3%
		Moyle	5.6	10.9	24.6	366,023	2,034,987	-7%	2%	-5%	-7%	2%	-5%
		Rail	8.4	25.6	9.0	9,507	79,428	-12%	2%	-10%	-12%	2%	-10%
Airport site (zone 60 71 75 77)							101,368	413%	17%	500%	413%	17%	500%
		Car	7.5	35.9	32.9	3,103	23,322	438%	22%	555%	438%	22%	555%
		Bus	7.0	0.0	49.1	4,827	33,726	409%	21%	514%	409%	21%	514%
		Walk	3.0	0.0	33.2	2,181	6,438	415%	-6%	382%	415%	-6%	382%
		Cycle	5.5	0.0	30.7	1,394	7,719	379%	10%	428%	379%	10%	428%
		Moyle	5.8	11.6	29.2	4,926	28,434	409%	14%	482%	409%	14%	482%
		Rail	8.3	24.6	9.9	209	1,728	458%	16%	545%	458%	16%	545%
Feng-chia (zone 74 only)							19,430	-12%	-14%	-24%	-12%	-14%	-24%
		Car	7.6	36.4	33.8	591	4,513	-13%	-12%	-24%	-13%	-12%	-24%
		Bus	7.3	0.0	50.7	901	6,555	-18%	-9%	-25%	-18%	-9%	-25%
		Walk	3.1	0.0	35.7	381	1,184	15%	-21%	-10%	15%	-21%	-10%
		Cycle	5.8	0.0	32.0	265	1,547	-13%	-16%	-27%	-13%	-16%	-27%
		Moyle	5.9	11.9	30.3	931	5,509	-17%	-11%	-26%	-17%	-11%	-26%
		Rail	9.7	24.7	12.9	13	122	-32%	2%	-30%	-32%	2%	-30%

The rest of the study area	NMKT	All	3.2	4.8	23.6	799,115	2,533,666	-4%	0%	-4%	-7%	2%	-5%
		Car	3.3	14.3	20.4	151,546	493,755	-3%	0%	-4%	-6%	1%	-5%
		Bus	5.8	0.0	48.5	152,482	886,687	-5%	0%	-5%	-8%	4%	-4%
		Walk	1.2	0.0	18.0	158,183	187,962	-4%	1%	-4%	-8%	0%	-7%
		Cycle	2.9	0.0	19.4	53,210	153,773	-4%	0%	-3%	-7%	2%	-6%
		Moyle	2.8	5.6	16.0	280,882	789,855	-4%	0%	-4%	-7%	1%	-6%
		Rail	7.6	24.7	8.8	2,812	21,511	-5%	-1%	-6%	-16%	1%	-16%
Airport site (zone 60 71 75 77)	NMKT	All	3.6	4.9	27.0	15,024	53,889	171%	-22%	112%	350%	21%	456%
		Car	5.3	29.7	29.8	1,380	7,299	184%	-36%	81%	425%	5%	449%
		Bus	5.5	0.0	45.1	4,153	22,848	177%	-29%	97%	447%	8%	492%
		Walk	1.5	0.0	18.9	3,376	5,073	201%	19%	257%	334%	30%	464%
		Cycle	3.3	0.0	19.9	1,070	3,514	168%	-15%	127%	346%	22%	447%
		Moyle	3.0	6.1	18.4	4,985	14,711	141%	-20%	93%	287%	29%	398%
		Rail	7.4	23.8	10.1	60	444	208%	-6%	189%	463%	12%	535%
Feng-chia (zone 74 only)	NMKT	All	5.8	6.8	34.0	18,170	104,782	36%	-28%	-3%	19%	-26%	-12%
		Car	9.3	40.1	34.3	1,816	16,915	48%	-38%	-8%	32%	-36%	-16%
		Bus	9.3	0.0	57.5	5,586	51,908	31%	-29%	-7%	17%	-27%	-15%
		Walk	1.6	0.0	20.7	3,401	5,277	66%	7%	78%	46%	6%	54%
		Cycle	4.4	0.0	25.5	1,253	5,489	34%	-24%	2%	16%	-23%	-11%
		Moyle	4.1	8.3	21.7	6,079	24,834	19%	-23%	-8%	3%	-21%	-19%
		Rail	10.4	25.9	12.6	35	359	-32%	0%	-32%	-41%	2%	-40%

Table 5-10 Comparison of travel demand by activity by mode: BAU 2041 vs RaSnAS 2041

Table 5-10 also shows the relationship between the airport site and Feng-chia precinct. The total number of trip volume of night time activities to Feng-chia will increase. This means the increased number of students, employees, tourists, and people living at the site not only provide source of demand for night time activities to the airport site itself but also to the nearby area. Table 5-11 to Table 5-13 further summarise the travel demand relating to Feng-chia precinct by time period.

Table 5-11 shows the travel demand to and from Feng-chia precinct under Existing 2013 scenario. Overall, there are more trips during the PM and Evening periods than the AM and Interpeak periods. This reflects the fact that the area attracts people with its abundant night time activities. Under the BAU 2041 scenario (Table 5-12), the trips of all types to and from Feng-chia will increase compared to the Existing 2013 scenario and this is in line with the fact that Feng-chia is in Xi-tun district which will see both number of household and population increase in the future (Figure 5-1 and Figure 5-2). However, under the RaSnAS 2041 scenario (Table 5-13) compared to the BAU 2041 scenario, trip made to and from Feng-chia during AM and Interpeak periods will reduce and during PM and evening periods the trips will increase. Intra-zonal travel of all types will reduce. This is in line with the results shown in Table 5-10 above that the attractiveness of the nearby airport site is relatively large that all types of trips will be diverted to the airport site. On the other hand, the new development of housing and schools within the site will support the prosperity of the night time activities in Feng-chia precinct.



Existing 2013							
Origin	Destination	Time period	Ave. distance	Ave. cost	Ave. time	FlowVol.	Trip-km
Feng-chia (zone 74)	The rest of study area	AM	6.74	18.65	33.05	8,212	55,382
The rest of study area	Feng-chia (zone 74)	AM	7.03	14.27	38.10	29,999	211,042
Feng-chia (zone 74)	Feng-chia (zone 74)	AM	0.97	2.37	11.60	2,602	2,519
		Total	6.59	14.40	35.39	40,813	268,944
Feng-chia (zone 74)	The rest of study area	IP	7.09	17.55	36.37	4,576	32,421
The rest of study area	Feng-chia (zone 74)	IP	6.96	17.29	37.55	4,384	30,497
Feng-chia (zone 74)	Feng-chia (zone 74)	IP	1.01	2.78	11.44	719	728
		Total	6.58	16.34	35.05	9,679	63,646
Feng-chia (zone 74)	The rest of study area	PM	7.26	13.53	41.62	34,801	252,673
The rest of study area	Feng-chia (zone 74)	PM	7.42	14.15	42.92	17,612	130,696
Feng-chia (zone 74)	Feng-chia (zone 74)	PM	1.02	2.19	13.35	6,090	6,219
		Total	6.66	12.54	39.07	58,503	389,589
Feng-chia (zone 74)	The rest of study area	Eve	7.78	13.20	37.99	12,597	97,939
The rest of study area	Feng-chia (zone 74)	Eve	8.02	11.85	40.76	7,933	63,596
Feng-chia (zone 74)	Feng-chia (zone 74)	Eve	1.05	2.02	14.07	4,138	4,348
		Total	6.72	10.89	34.87	24,667	165,883
Total			6.64	13.08	36.88	133,662	888,062

Table 5-11 Travel demand relating to Feng-chia precinct under Existing 2013 scenario

BAU 2041							
Origin	Destination	Time period	Ave. cost %	Ave. time %	Ave. distance %	FlowVol. %	Trip-km %
Feng-chia (zone 74)	The rest of study area	AM	-3%	0%	-1%	18%	17%
The rest of study area	Feng-chia (zone 74)	AM	-8%	-3%	-4%	16%	11%
Feng-chia (zone 74)	Feng-chia (zone 74)	AM	0%	0%	0%	17%	17%
		Total	-7%	-2%	-4%	16%	12%
Feng-chia (zone 74)	The rest of study area	IP	-6%	-2%	-4%	16%	12%
The rest of study area	Feng-chia (zone 74)	IP	-6%	-1%	-3%	16%	13%
Feng-chia (zone 74)	Feng-chia (zone 74)	IP	0%	0%	0%	17%	17%
		Total	-6%	-2%	-3%	16%	12%
Feng-chia (zone 74)	The rest of study area	PM	-8%	-4%	-5%	14%	8%
The rest of study area	Feng-chia (zone 74)	PM	-3%	-2%	-2%	12%	10%
Feng-chia (zone 74)	Feng-chia (zone 74)	PM	1%	-1%	0%	8%	7%
		Total	-6%	-3%	-3%	13%	9%
Feng-chia (zone 74)	The rest of study area	Eve	-5%	-2%	-4%	9%	5%
The rest of study area	Feng-chia (zone 74)	Eve	-1%	0%	0%	6%	6%
Feng-chia (zone 74)	Feng-chia (zone 74)	Eve	1%	0%	0%	3%	3%
		Total	-2%	-1%	-2%	7%	5%
Total			-6%	-2%	-3%	13%	9%

Table 5-12 Travel demand relating to Feng-chia precinct under BAU 2041 scenario in relation to Existing 2013

RaSnAS 2041							
Origin	Destination	Time period	Ave. cost %	Ave. time %	Ave. distance %	FlowVol. %	Trip-km %
Feng-chia (zone 74)	The rest of study area	AM	-18%	-11%	-21%	2%	-20%
The rest of study area	Feng-chia (zone 74)	AM	0%	0%	0%	-7%	-7%
Feng-chia (zone 74)	Feng-chia (zone 74)	AM	-2%	0%	-1%	-23%	-24%
		Total	-4%	-2%	-4%	-6%	-10%
Feng-chia (zone 74)	The rest of study area	IP	-7%	-5%	-8%	-6%	-14%
The rest of study area	Feng-chia (zone 74)	IP	-8%	-7%	-11%	-5%	-15%
Feng-chia (zone 74)	Feng-chia (zone 74)	IP	1%	0%	-4%	-33%	-36%
		Total	-6%	-4%	-7%	-8%	-14%
Feng-chia (zone 74)	The rest of study area	PM	-9%	-6%	-9%	3%	-6%
The rest of study area	Feng-chia (zone 74)	PM	-23%	-15%	-23%	18%	-9%
Feng-chia (zone 74)	Feng-chia (zone 74)	PM	-1%	0%	0%	-18%	-18%
		Total	-12%	-7%	-12%	6%	-7%
Feng-chia (zone 74)	The rest of study area	Eve	-22%	-13%	-24%	25%	-5%
The rest of study area	Feng-chia (zone 74)	Eve	-32%	-21%	-35%	44%	-6%
Feng-chia (zone 74)	Feng-chia (zone 74)	Eve	-1%	0%	0%	-17%	-17%
		Total	-22%	-13%	-24%	24%	-6%
Total			-10%	-6%	-11%	4%	-8%

Table 5-13 Travel demand relating to Feng-chia precinct under RaSnAS 2041 scenario in relation to BAU 2041

By aggregating each type of trips based on time period and compare each scenario with the BAU 2041, Figure 5.16 below shows the percentage change of people flows from any

one zone to zone 60, which attracts the most flows among all zones in the airport site. Most changes are around 15 – 20 times for AM peak period, 5 -15 times for Interpeak period, 0-5 times for PM peak period and 0-5 times for Evening peak period. However, the considerable changes in some zones, especially the ones further away from the airport site, are in fact based on small absolute flow volume in the BAU scenario. Figure 5.17 shows the flow volume drawn to destination zone 60 in absolute terms under the RaSnAS 2041 scenario. The number of flows generated from the zones further away from zone 60 are mostly under 500. For example, the zone at the northern tip of the city experience a 15 times flow change however this is based on only 3 trips made during the AM peak period under BAU 2041 scenario and 45 trips under RaSnAS 2041 scenario.

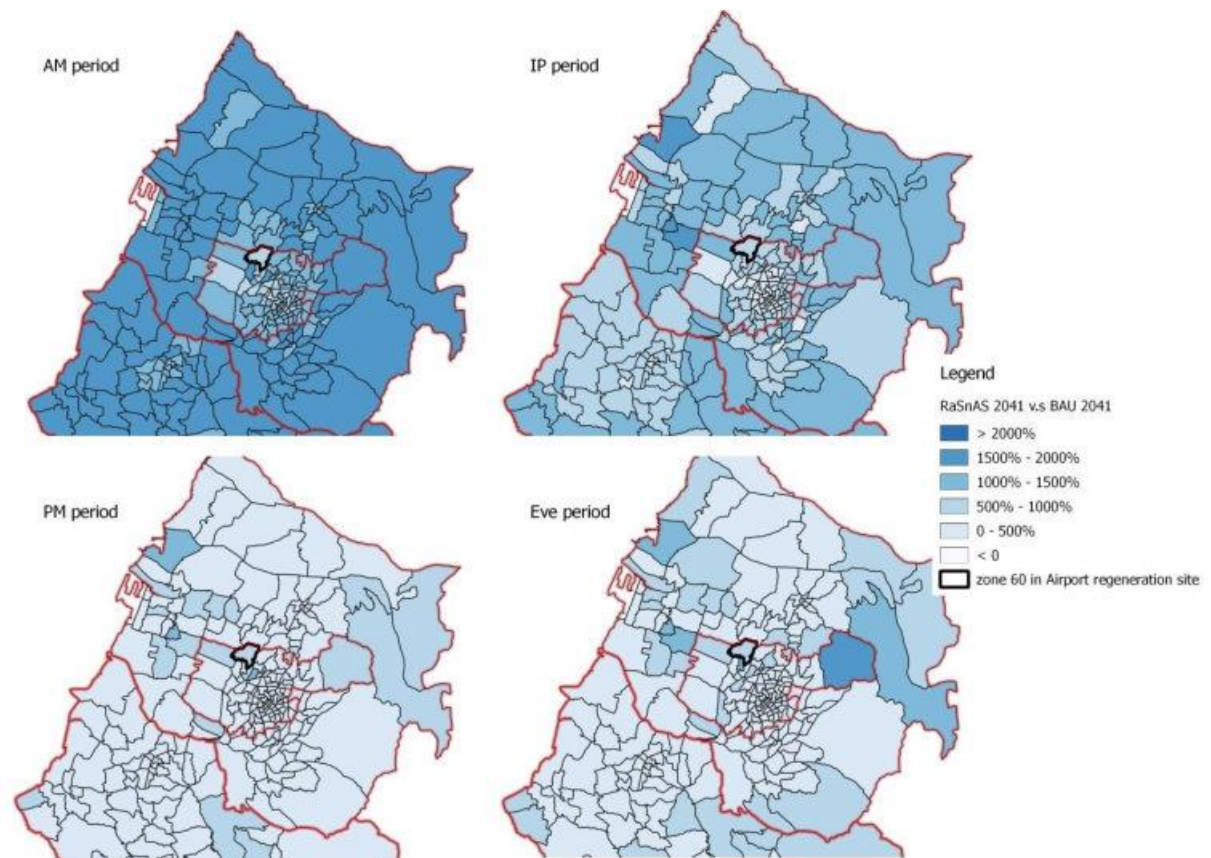


Figure 5-16 Comparison of passenger trip volume to zone 60

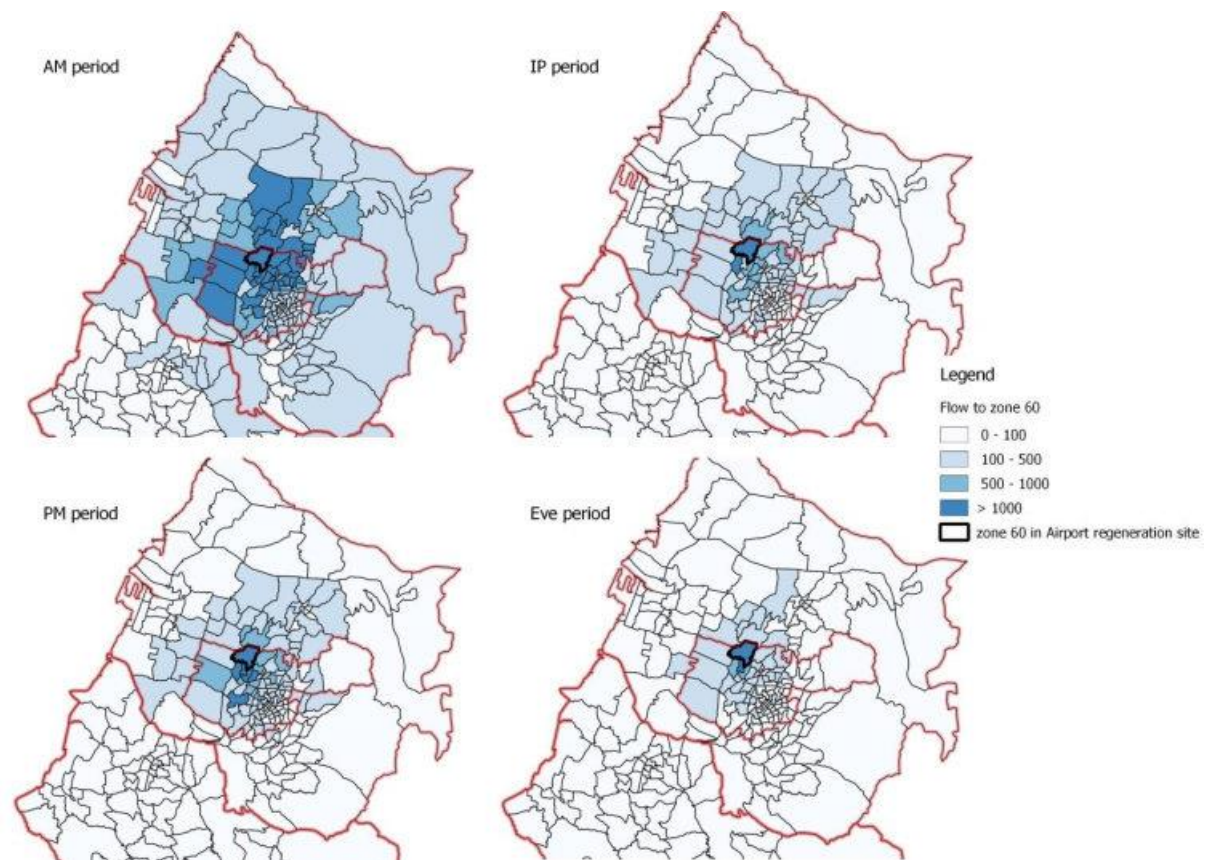


Figure 5-17 Passenger trip volume to zone 60 in airport site under RaSnAS 2041

### **5.3.2 Link traffic volumes under RaSnAS 2041**

This section looks at hourly traffic volumes of each inter-zonal link under RaSnAS 2041.

Figure 5-18 to Figure 5-21 below show the capacity ratio for each link for each peak hour for the RaSnAS 2041. Links that are over-capacity are shown in the thickest line with the links of over 50% capacity and still below the capacity highlighted in lighter hue. The rest of the links are loaded however are well under-capacity. In general, AM and PM peak hours have more over-capacity links than other two peak hours. AM peak has 1% more links than PM peak to have over-capacity links. As expected, the congested links concentrate in urban area. Some links are congested in the AM peak hour but not so in the PM peak hour with the opposite direction of links exhibit an otherwise pattern. During the Evening peak, very few links are over-capacity and they are only slight over the capacity. During the Inter peak hour there are no over-capacity links.

The following two figures look at the results from different angle. Figure 5-22 highlight the links which is over-capacity and whether this occurs during AM or PM peak hour. And Figure 5-23 shows the links which is between 50% and 100% capacity and whether this happens during the AM or PM peak hour. The results also show that all links take the maximum flow either during AM or PM peak hours.



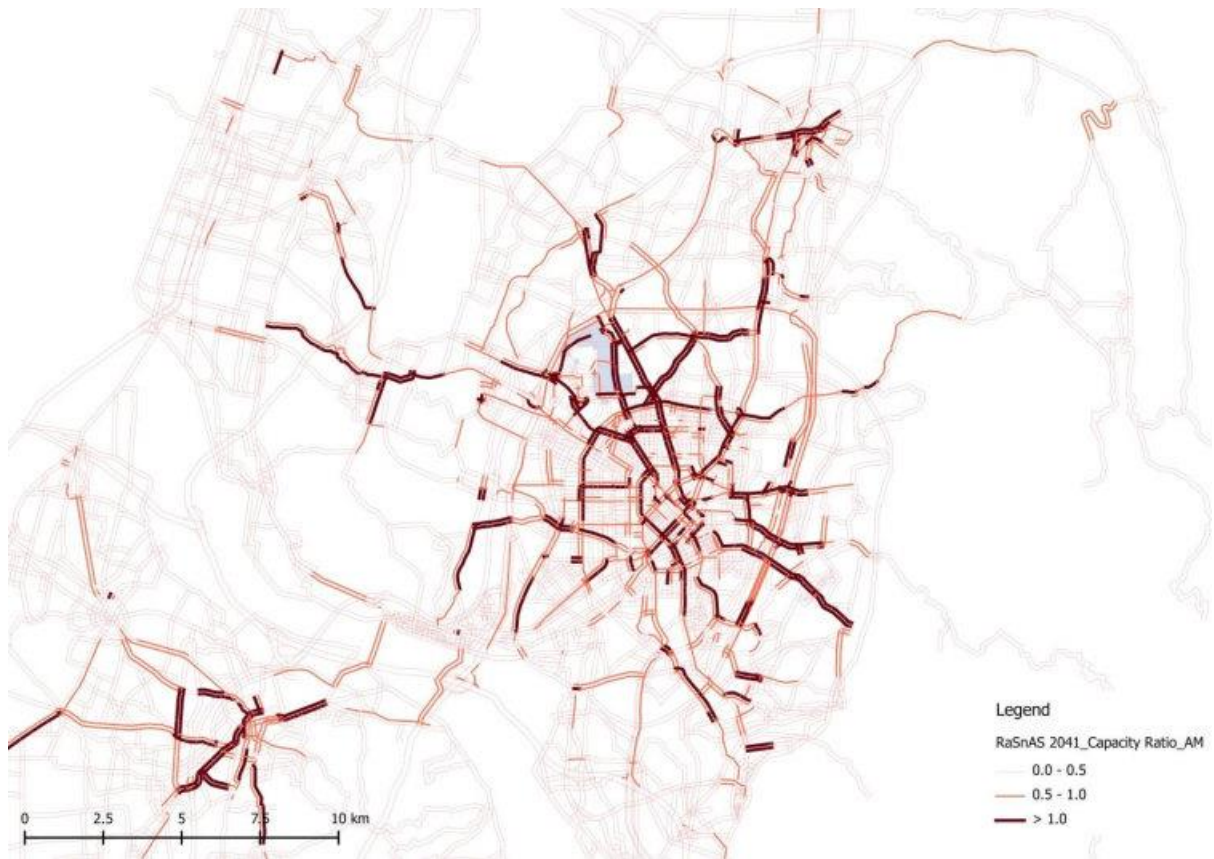


Figure 5-18 Link load/capacity ratio in AM peak hour for RaSnAS 2041

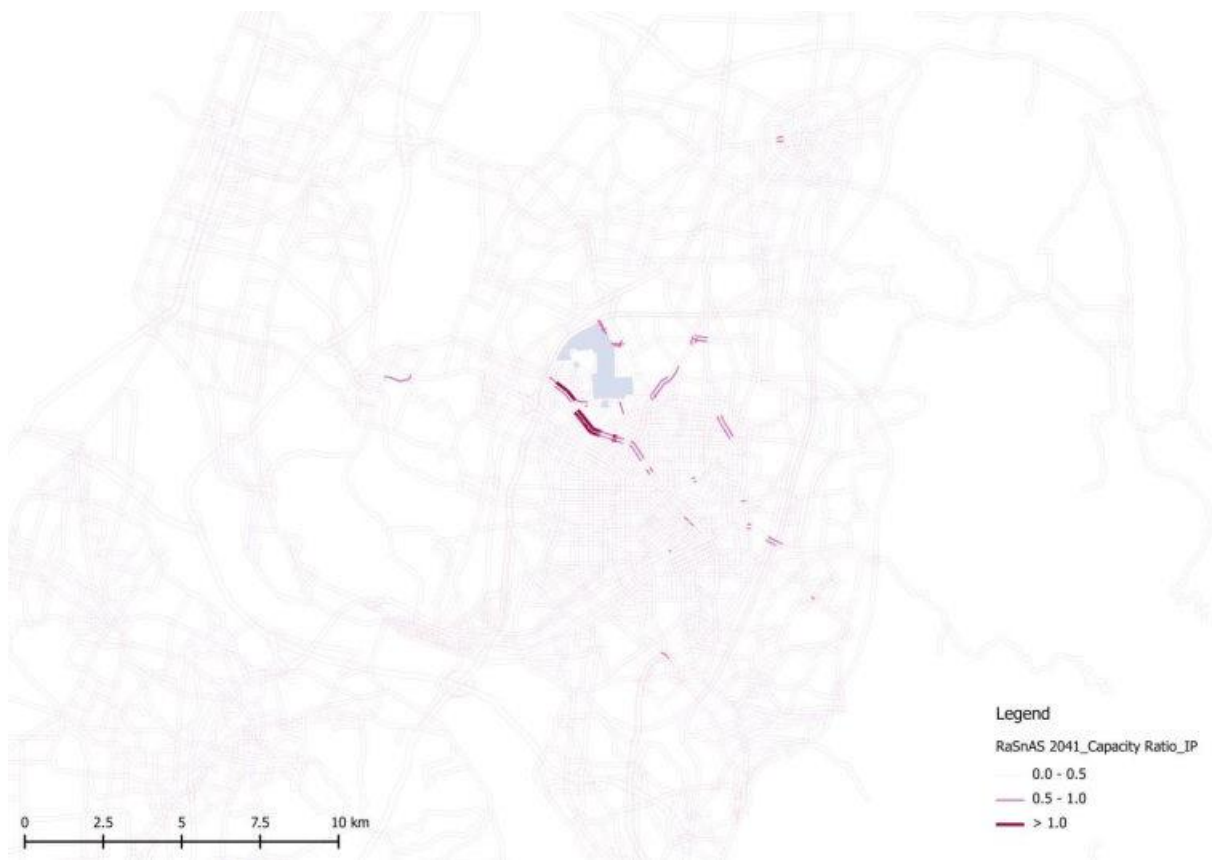


Figure 5-19 Link load/capacity ratio in Interpeak hour for RaSnAS 2041

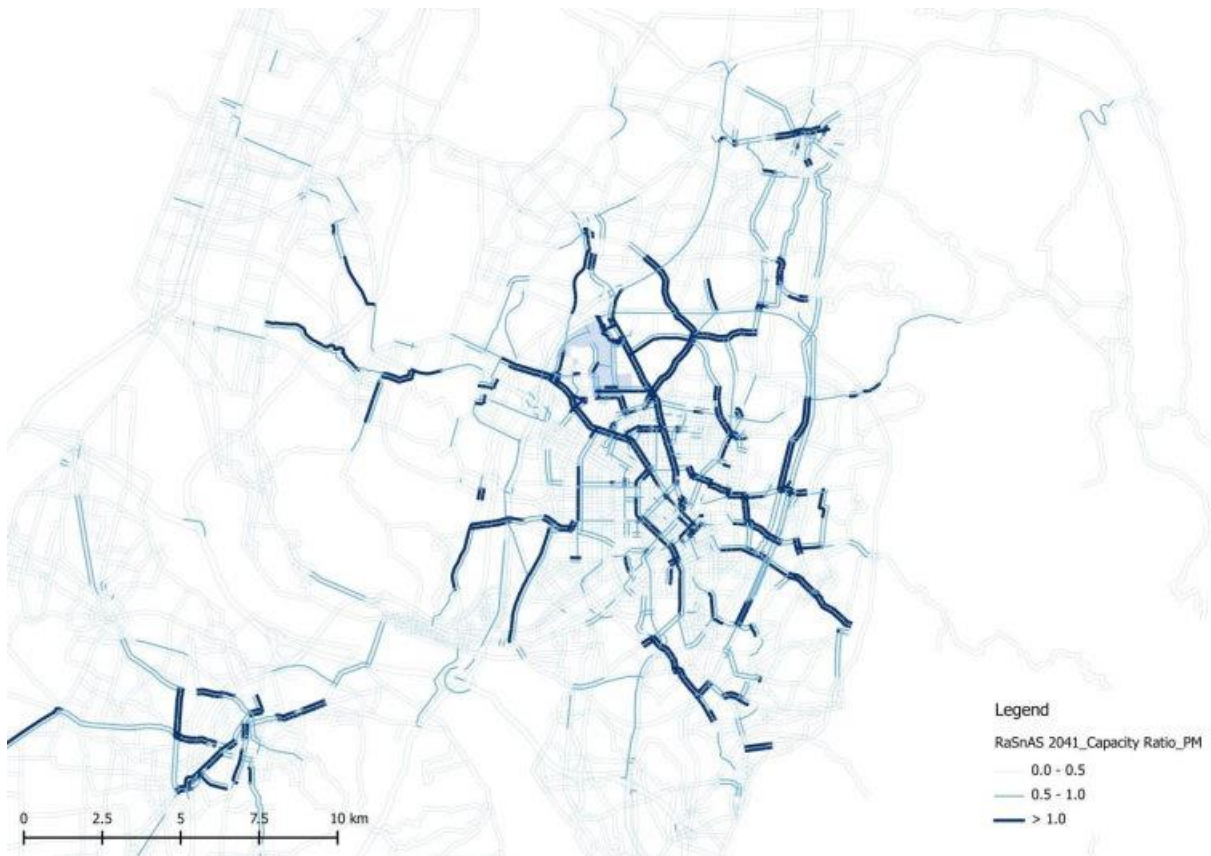


Figure 5-20 Link load/capacity ratio in PM peak hour for RaSnAS 2041

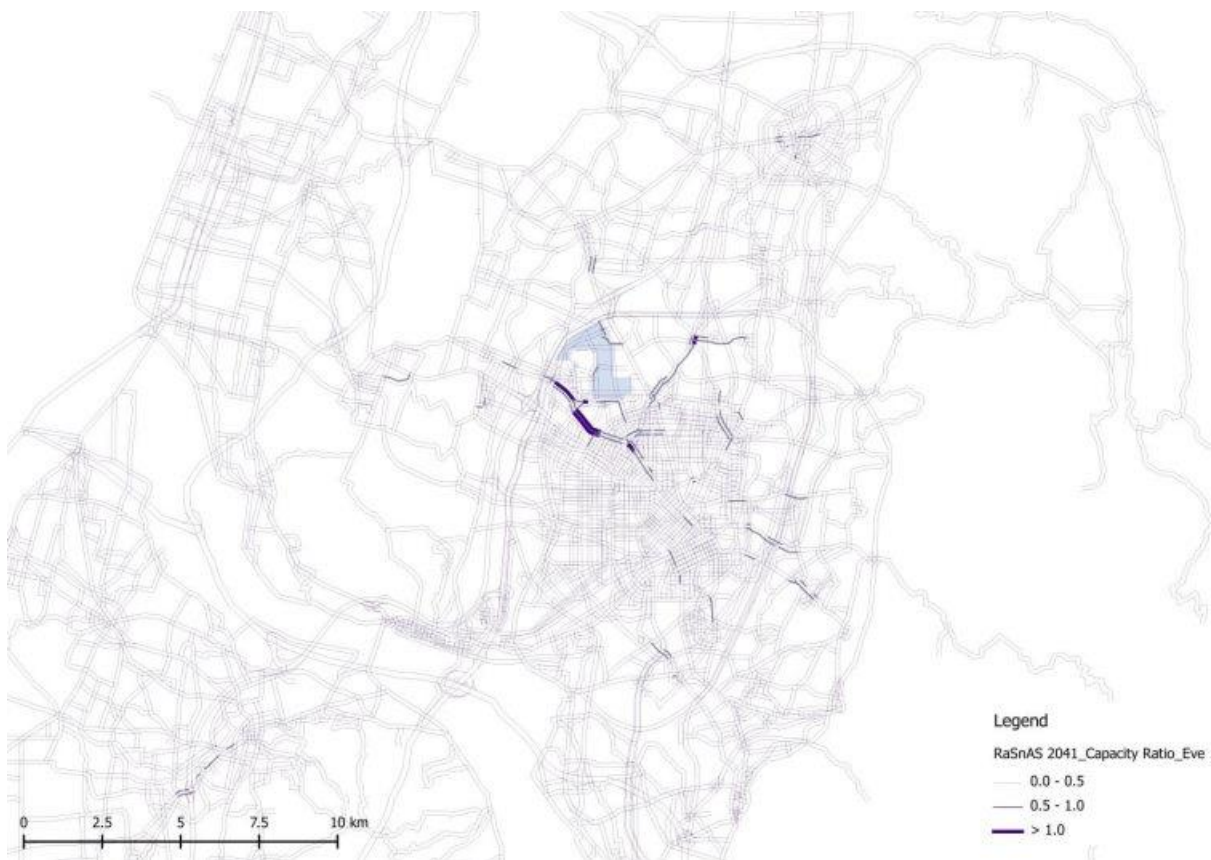


Figure 5-21 Link load/capacity ratio in Evening peak hour for RaSnAS 2041



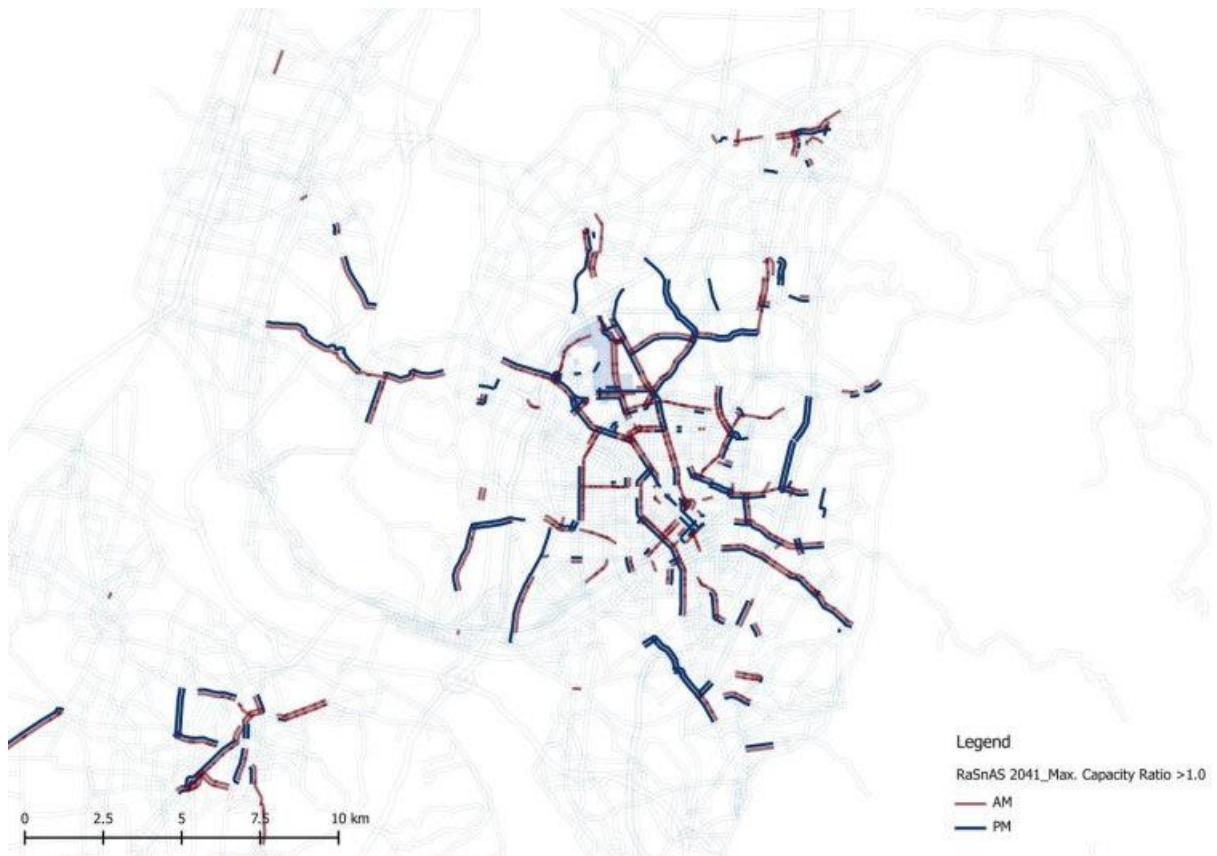


Figure 5-22 Maximum link load/capacity ratio > 1 by peak hour for RaSnAS 2041

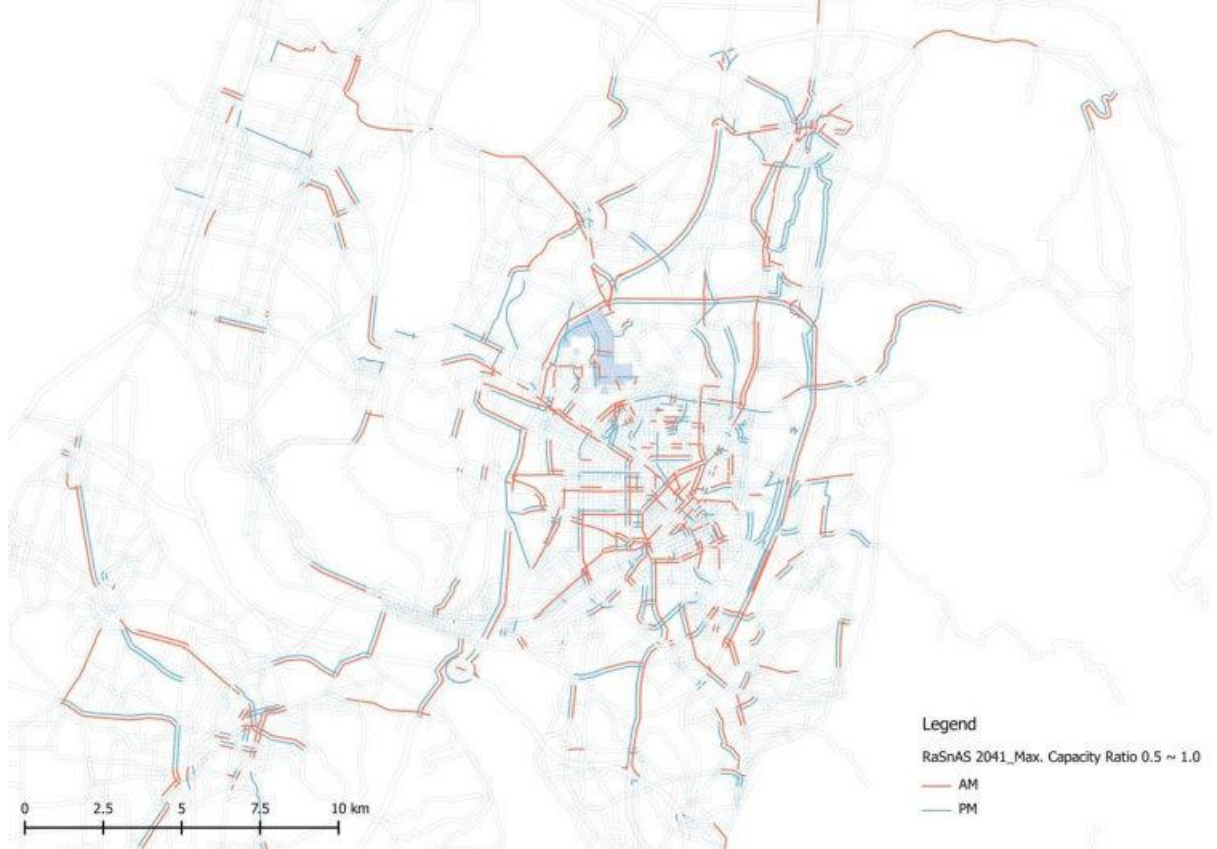


Figure 5-23 Maximum link load/capacity ratio between 0.5 and 1 by peak hour for RaSnAS 2041

### 5.3.3 Link traffic volumes comparison between RaSnAS 2041 and BAU 2041

Figure 5-24 to Figure 5-28 below shows the percentage changes brought about by the airport site in relation to the BAU 2041 scenario. Most of the links experience little to no changes during each hour (links experiencing -10% to 10% changes in Figure 5-24). For the links around the airport site, however, the changes are more noticeable. The red and orange links indicate the increase in traffic while the blue links means reduction in traffic flow after the airport site development. This confirms the pattern observed from previous section that the airport site attracts people which in turn reduce the number of people travelling to other areas in Taichung. Figure 5-29 highlights the links with increased hourly maximum flow between RaSnAS 2041 and BAU 2041. The following four figures, Figure 5-30 to Figure 5-33, show the period traffic flow under this circumstance.



Figure 5-24 Link flow change between RaSnAS 2041 and BAU 2041 in AM peak hour



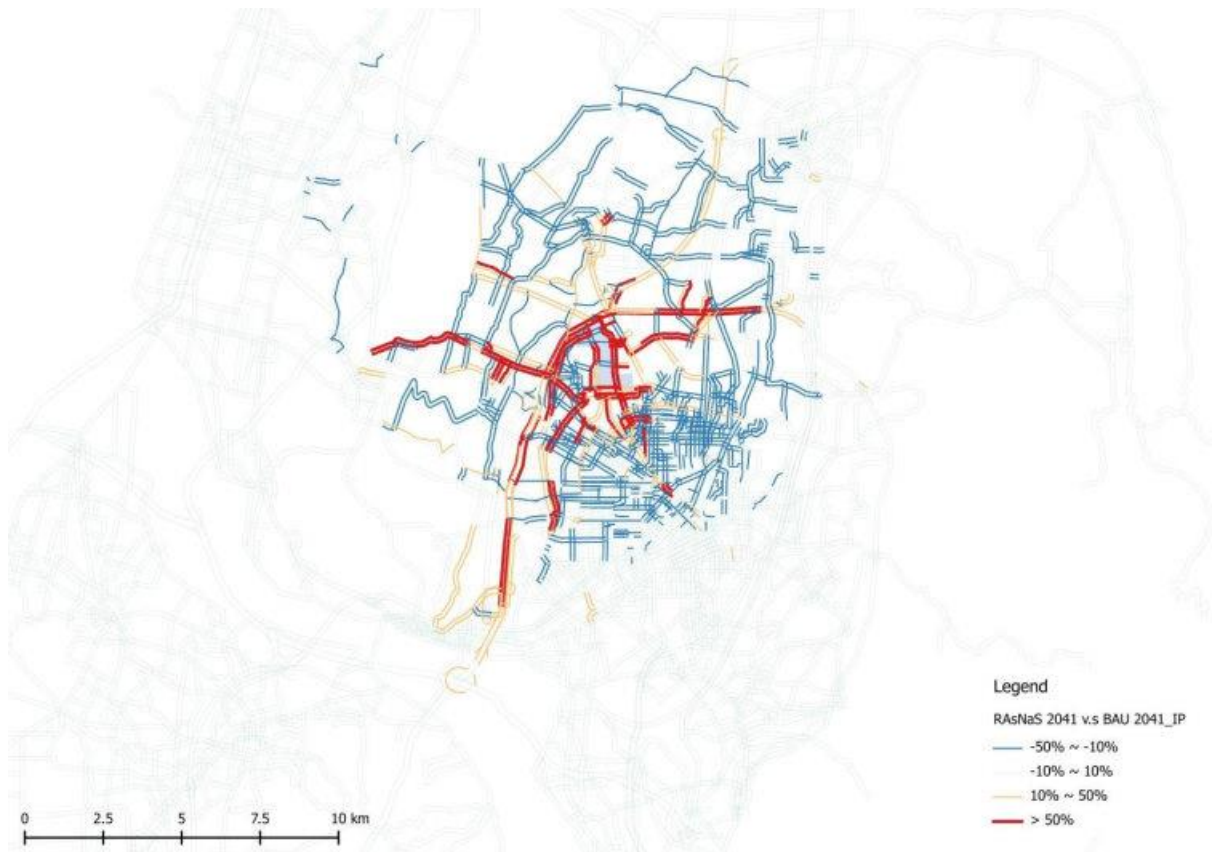


Figure 5-25 Link flow change between RaSnAS 2041 and BAU 2041 in Interpeak hour

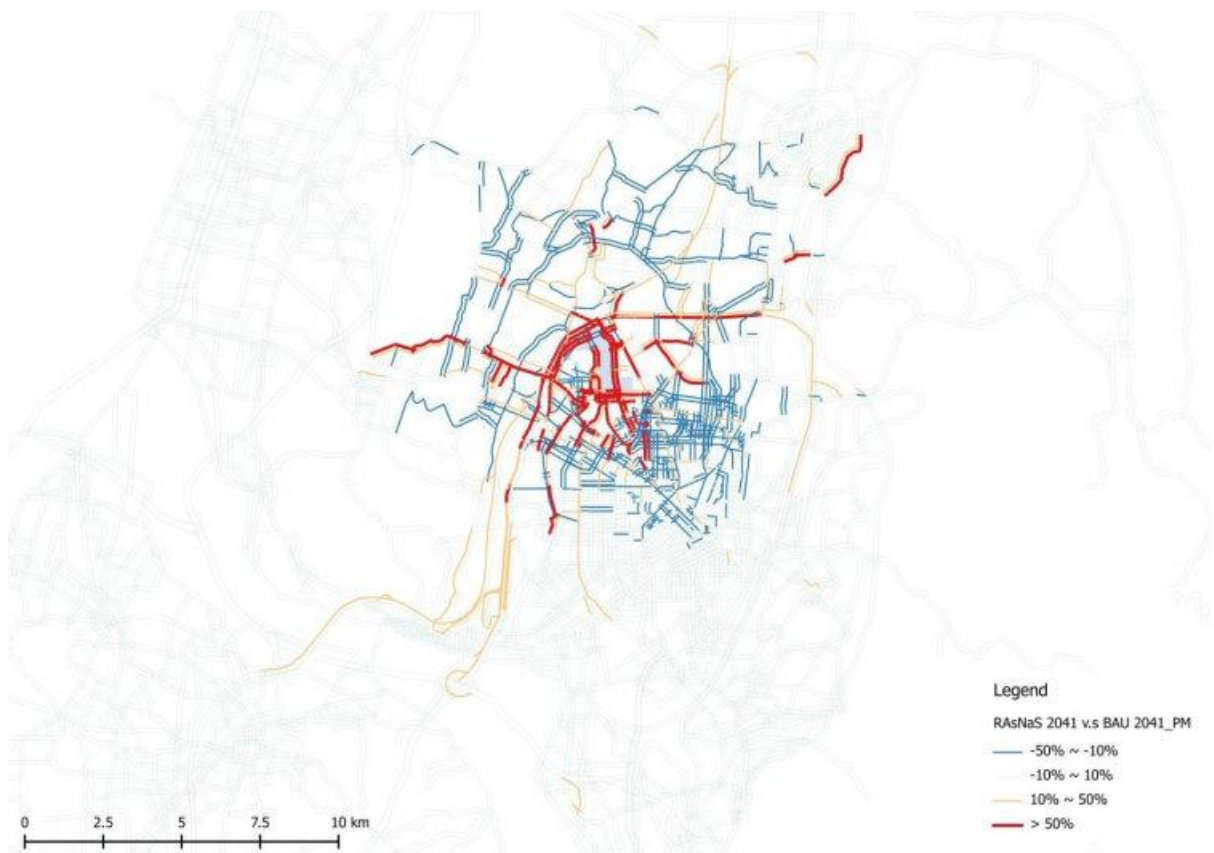


Figure 5-26 Link flow change between RaSnAS 2041 and BAU 2041 in PM peak hour

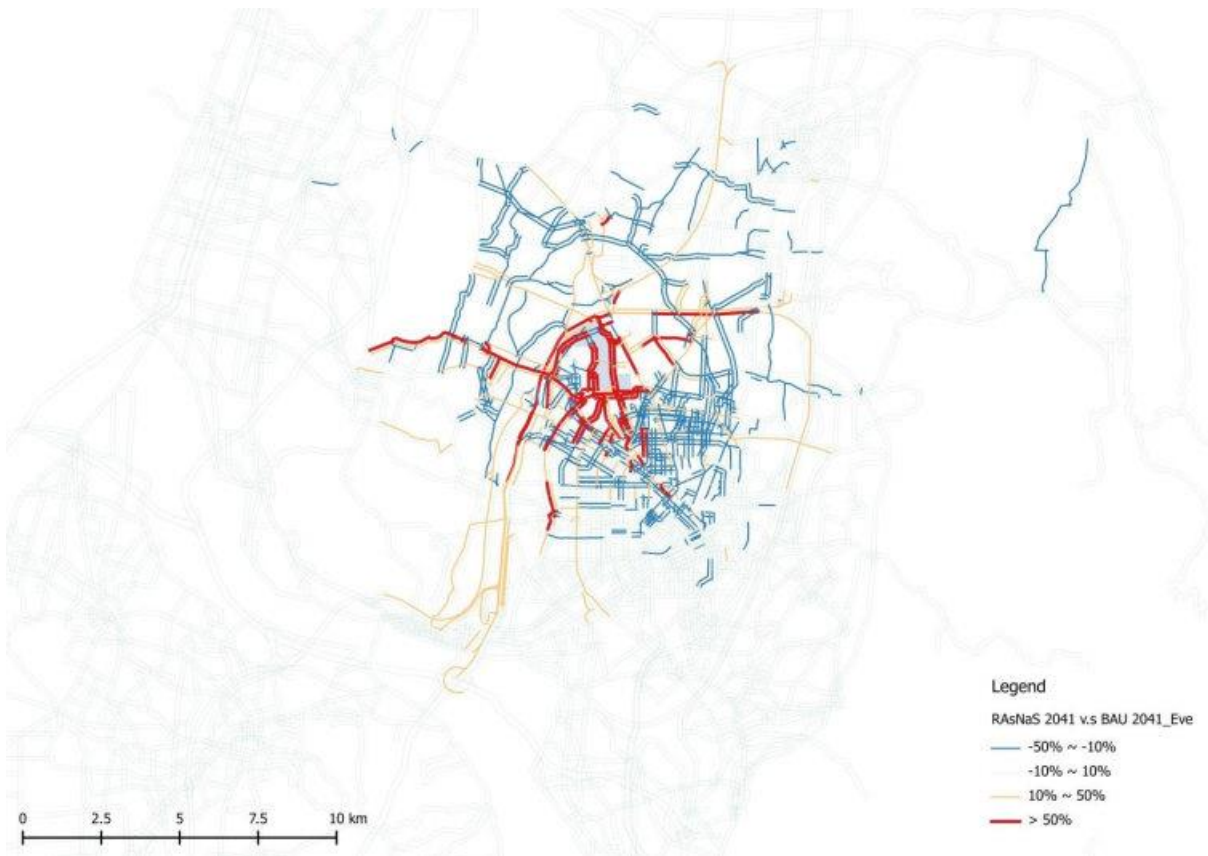


Figure 5-27 Link flow change between RaSnAS 2041 and BAU 2041 in Evening peak hour

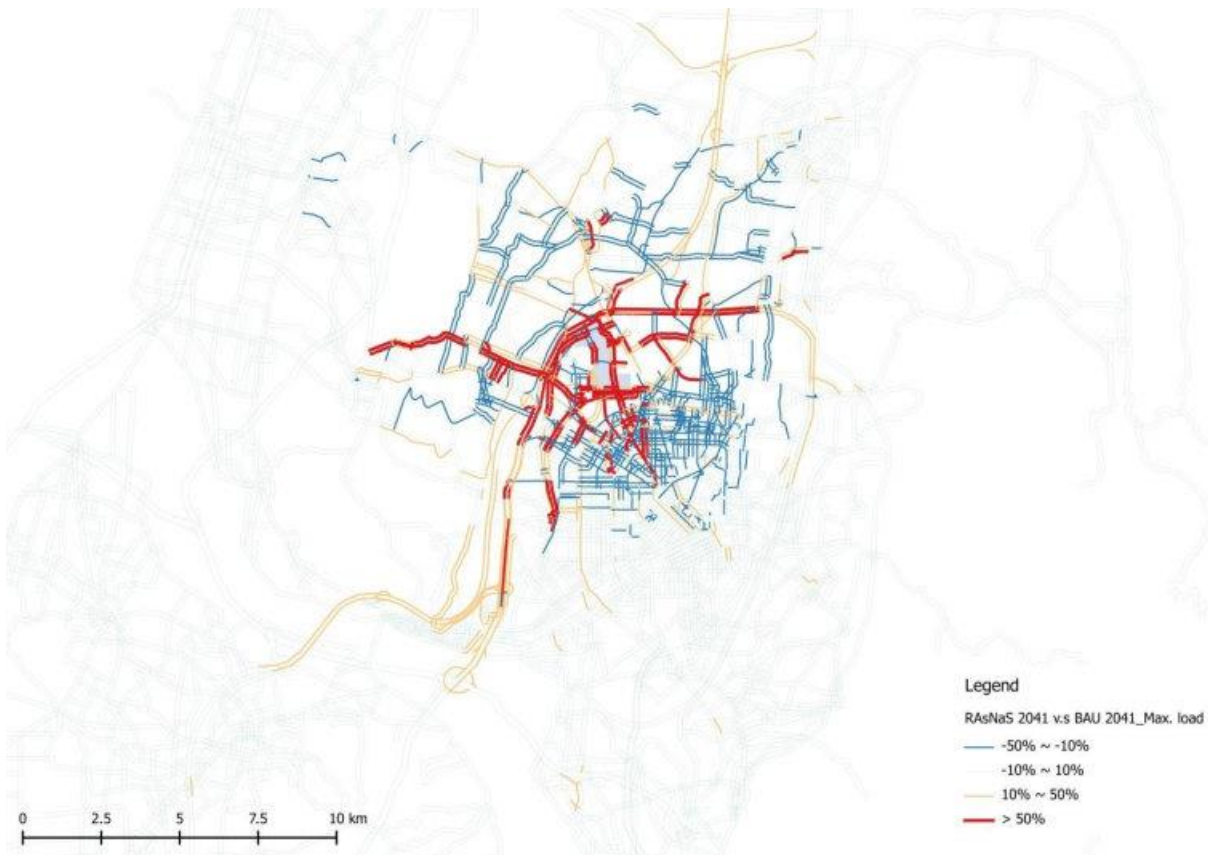


Figure 5-28 Maximum link flow change between RaSnAS 2041 and BAU 2041

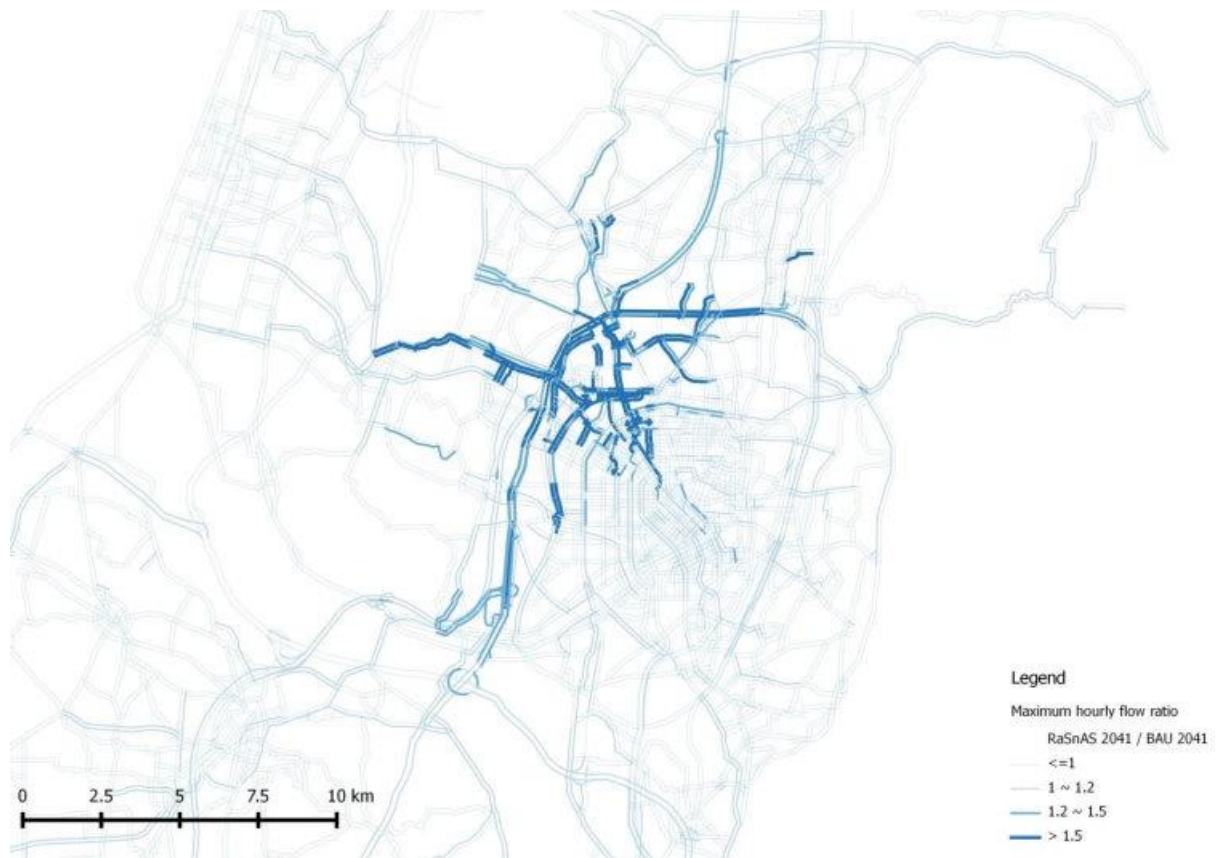


Figure 5-29 Ratio of maximum hourly link flow between RaSnAS 2041 and BAU 2041 scenario

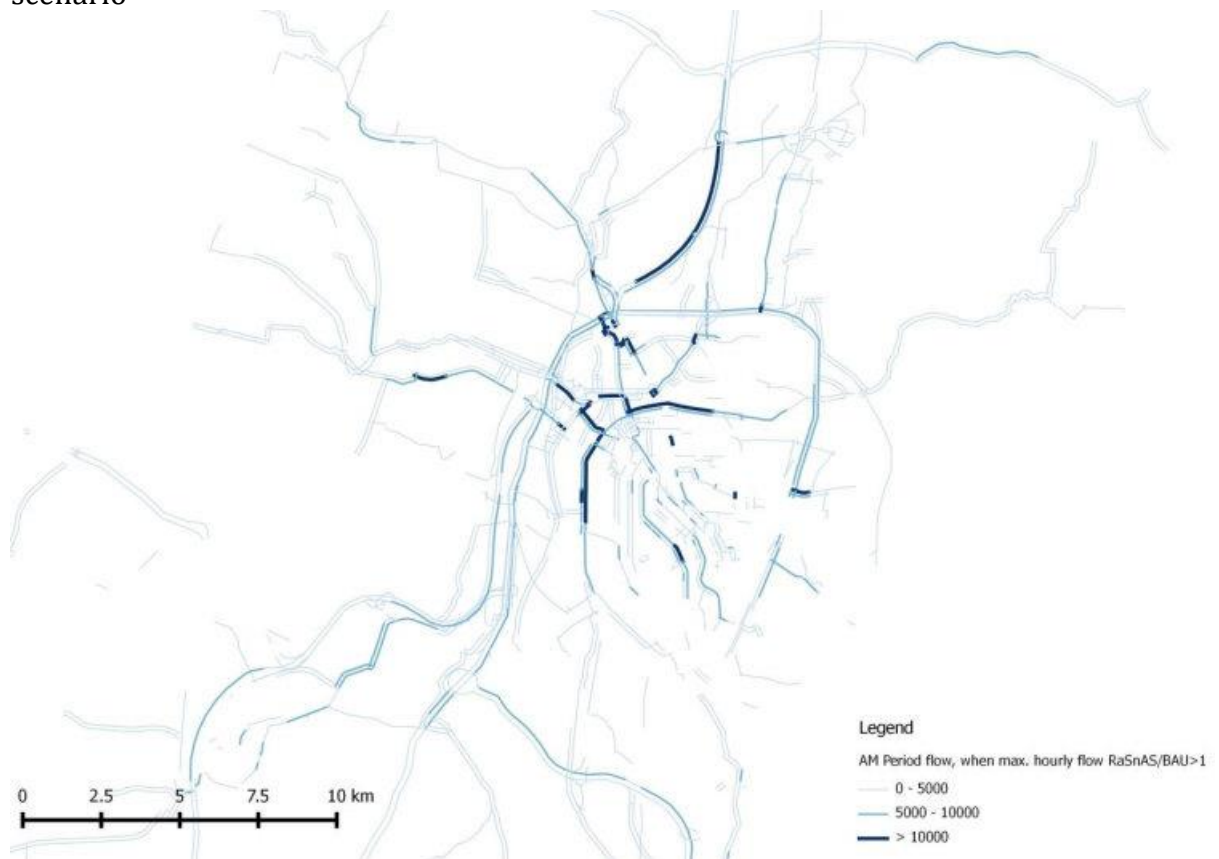


Figure 5-30 AM period flow when maximum hourly link flow RaSnAS 2041 > BAU 2041



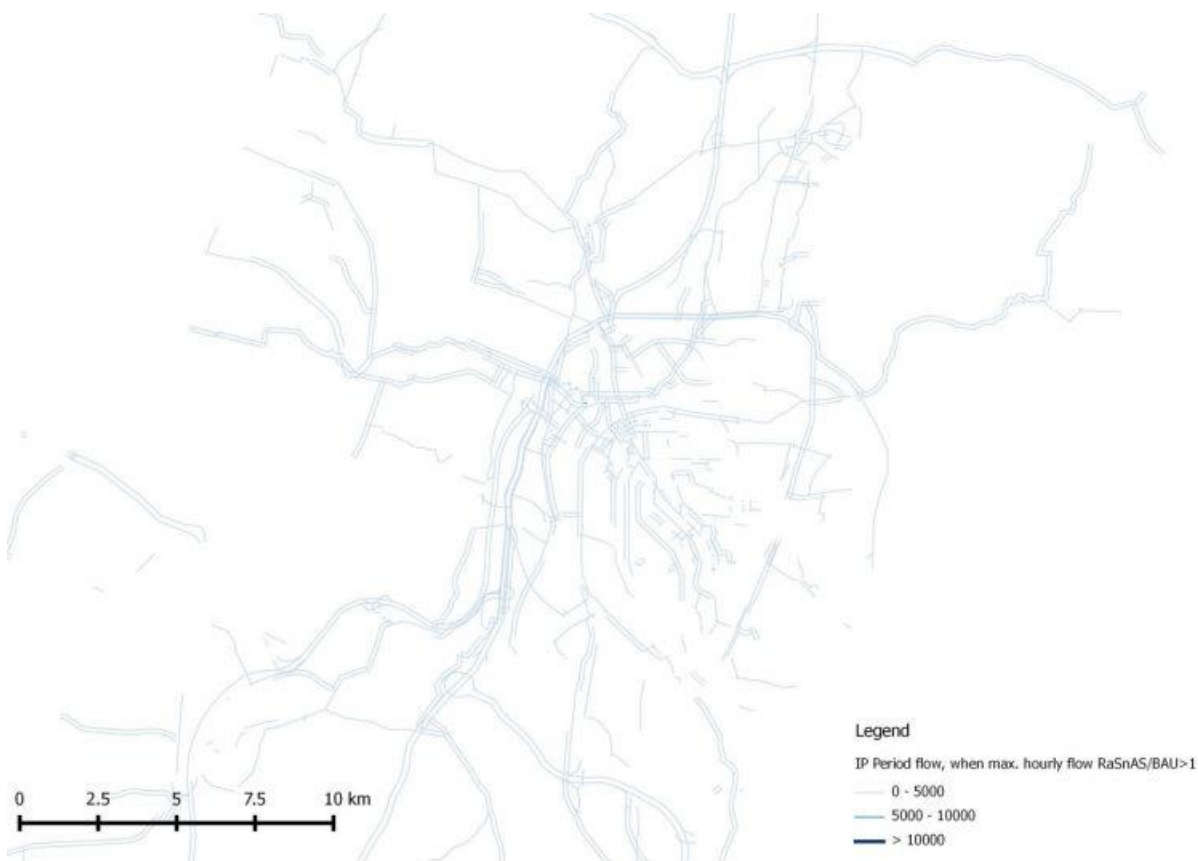


Figure 5-31 Interpeak period flow when maximum hourly link flow RaSnAS 2041 > BAU 2041

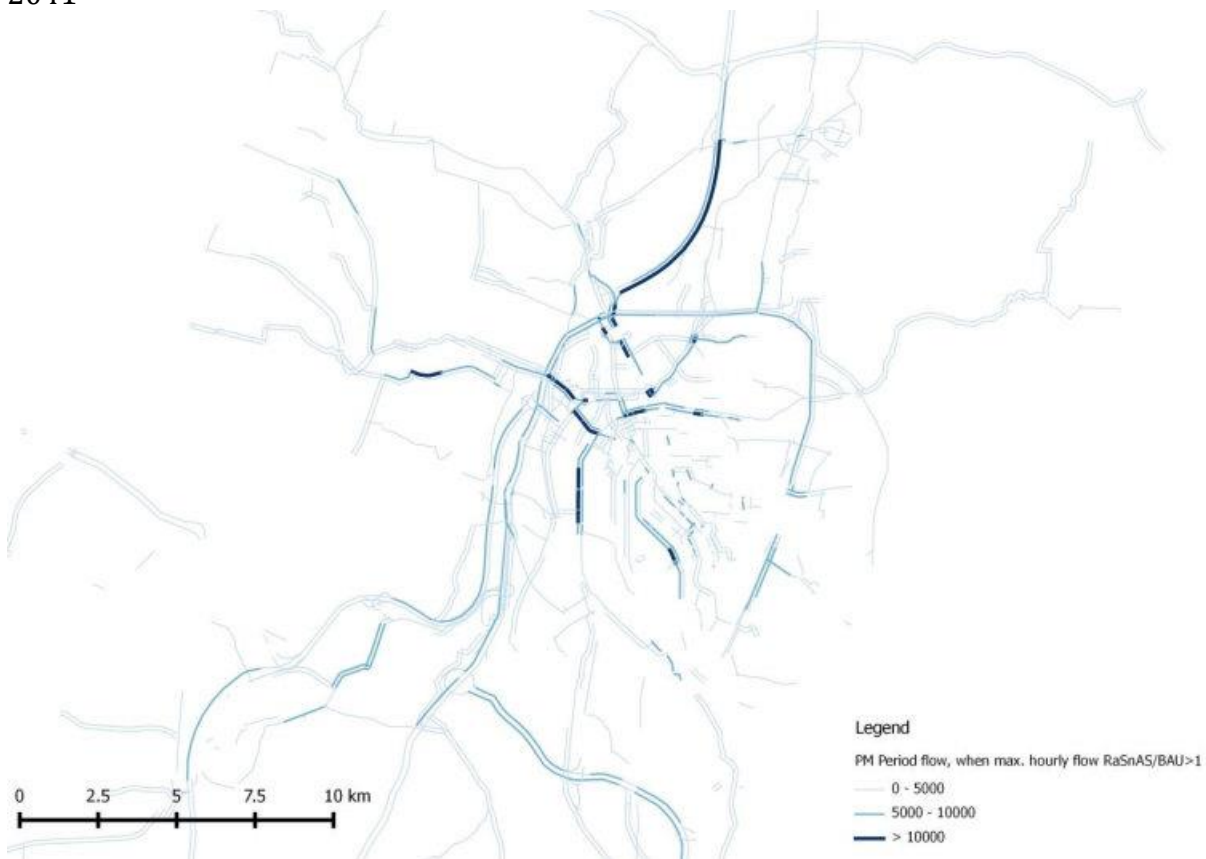


Figure 5-32 PM period flow when maximum hourly link flow RaSnAS 2041 > BAU 2041

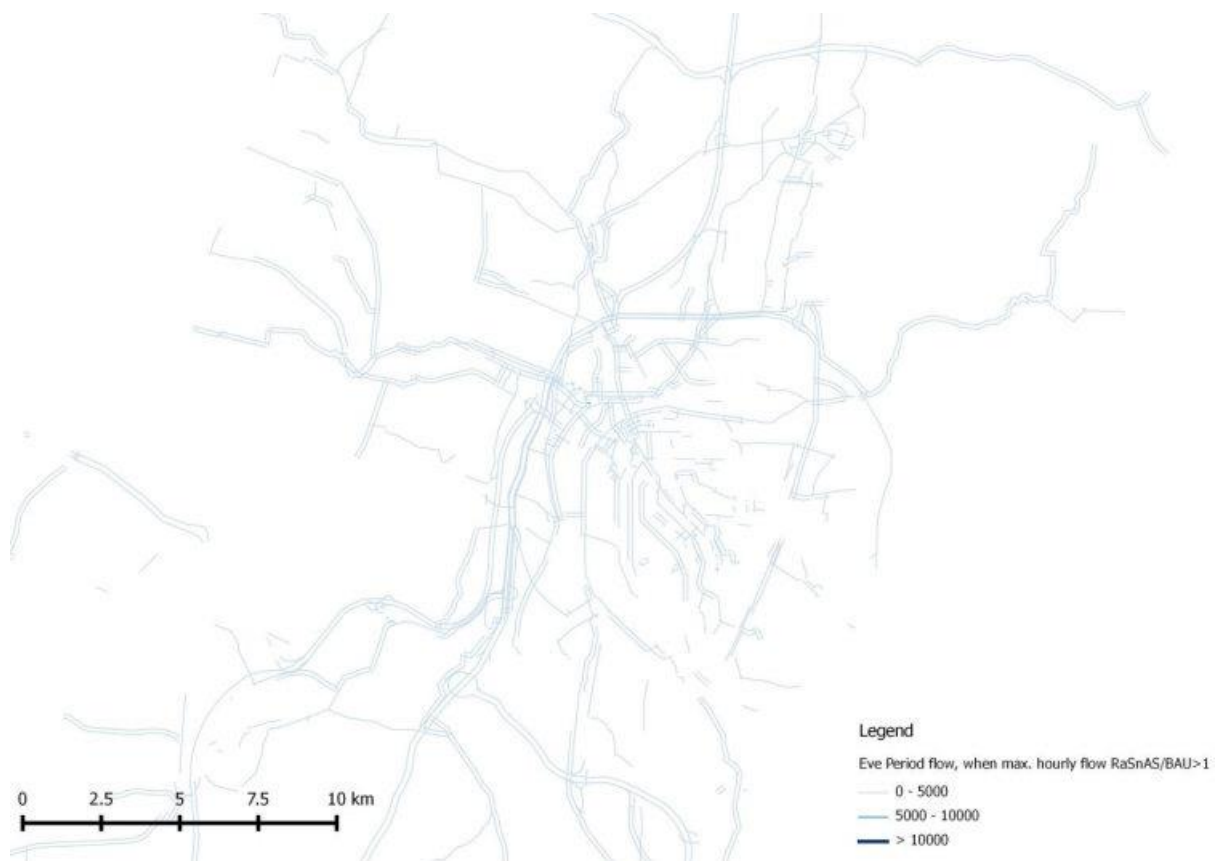


Figure 5-33 Evening period flow when maximum hourly link flow RaSnAS 2041 > BAU 2041

For the links which will have higher maximum hourly flow in the RsSnAS 2041 scenario than in BAU 2041, their link entropy is illustrated in the Figure 5-34. The weighted average entropy for RsSnAS 2041 being 1.2067. Most of these links will experience more fluctuation in flows among time periods.

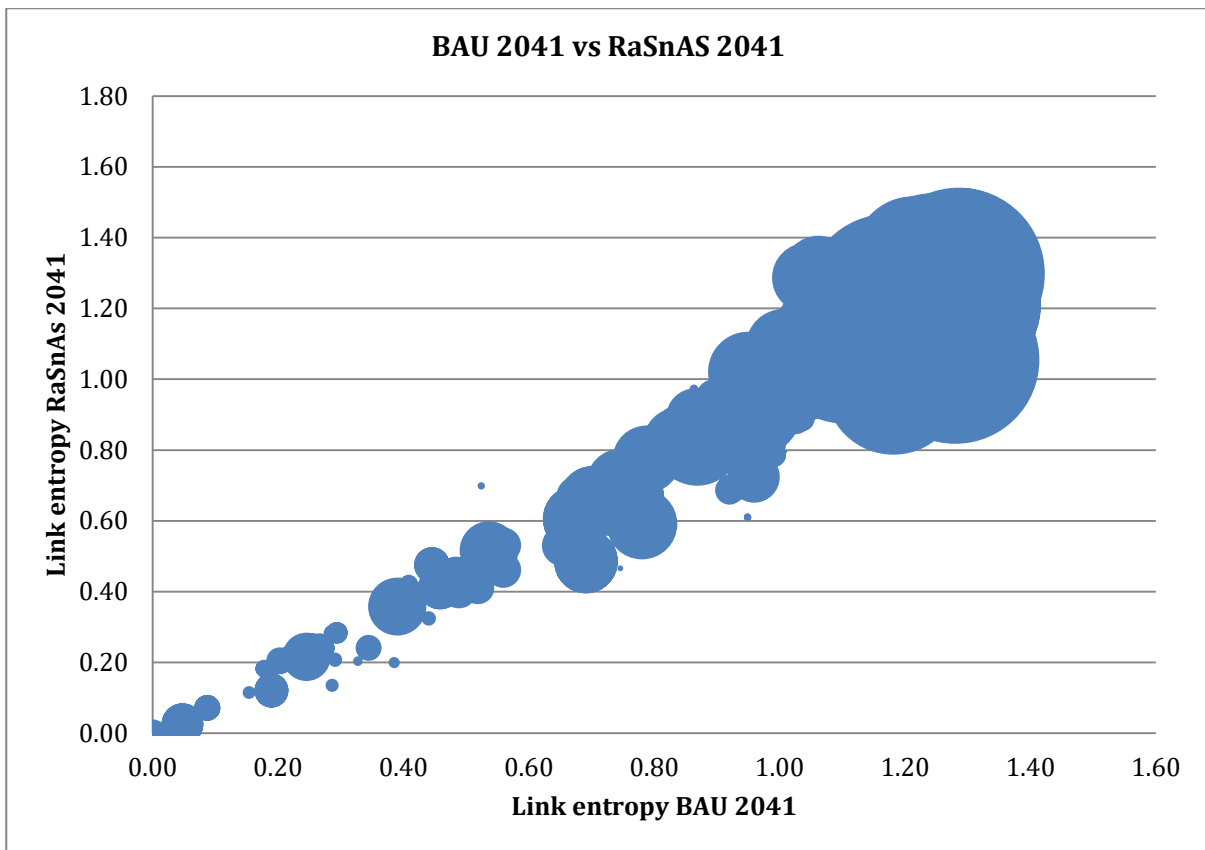


Figure 5-34 Link entropy between BAU 2041 and RaSnAS 2041 scenario

#### 5.4 The RS Scenario

The subcentres chosen for enhancing the regional development are illustrated in Figure 5-35. All the centres are expected to experience growth in the number of households and population in 2041. The land use changes are summarised in Table 5-14. As mentioned in the previous section, the increases in all the land use changes is assumed to cause a redistribution of population and households within Taichung in the long term.

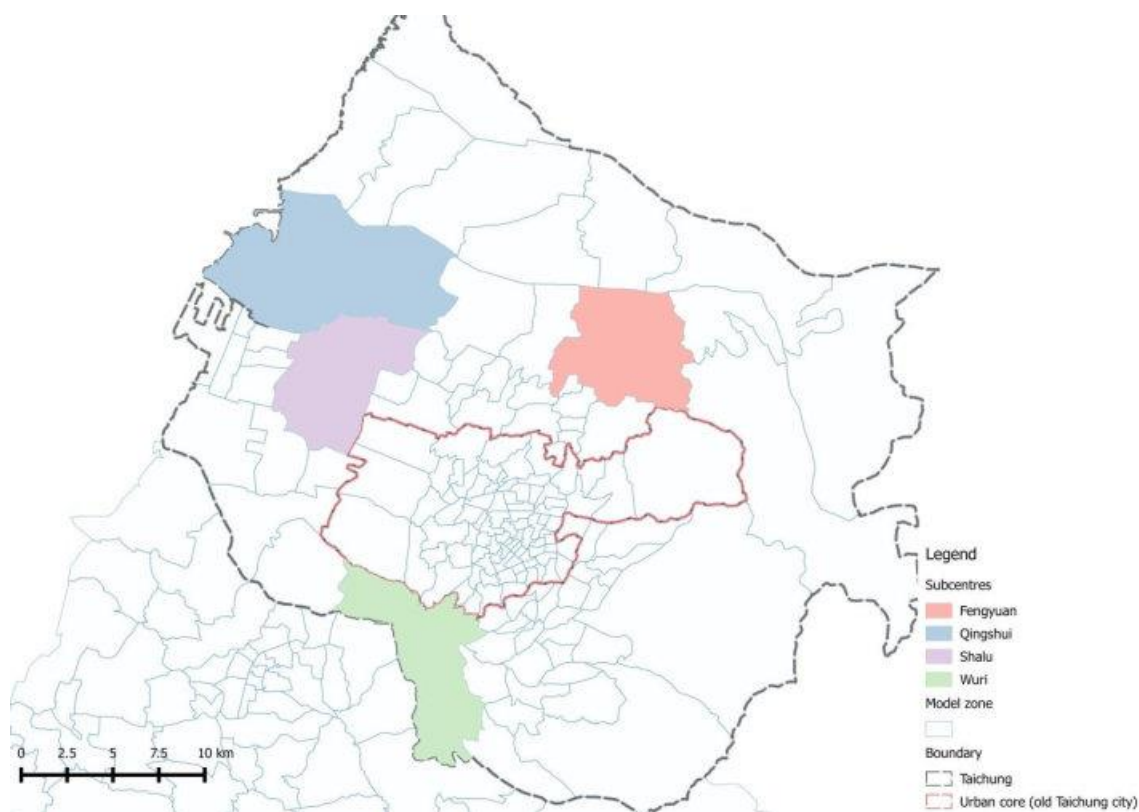


Figure 5-35 Location of subcentres in Taichung

Subcentre	Population change %	Household change %
Fengyuan	5.2%	22.2%
Qingshui	2.3%	20.2%
Shalu	21.6%	56.0%
Wuri	3.4%	24.3%

Table 5-14 Land use change in the subcentres compared to BAU 2041

#### 5.4.1 Travel demand between the zones

Table 5-15 shows the comparison between BAU 2041 and RS 2041 by trip purpose by mode and Table 5-16 shows the comparison by time period by mode. The results show that the overall flow volume by each segment will stay the same.

RS 2041						
Activity	Mode	Ave. distance %	Ave. cost %	Ave. time %	FlowVol. %	Trip-km %
HBW	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	0%	0%	0%	0%	0%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	1%	0%	0%	0%	0%
HBE	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	0%	0%	0%	0%	0%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	1%	0%	0%	0%	0%
HBO	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	1%	0%	0%	0%	1%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	1%	0%	0%	-1%	0%
NHB	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	1%	0%	0%	0%	1%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	1%	0%	0%	0%	1%
NMT	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	0%	0%	0%	0%	0%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	0%	0%	0%	0%	0%
Total		0%	0%	0%	0%	0%

Table 5-15 Travel demand comparison by trip purpose by mode between RS 2041 and BAU 2041



RS 2041						
Time period	Mode	Ave. distance %	Ave. cost %	Ave. time %	FlowVol. %	Trip-km %
AM	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	0%	0%	0%	0%	0%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	1%	0%	0%	0%	0%
IP	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	0%	0%	0%	0%	1%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	1%	0%	0%	0%	0%
PM	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	0%	0%	0%	0%	0%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	1%	0%	0%	0%	0%
Eve	Total	0%	0%	0%	0%	0%
	Car	0%	0%	0%	0%	0%
	Bus	0%	0%	0%	0%	0%
	Walk	0%	0%	0%	0%	0%
	Cycle	0%	0%	0%	0%	0%
	Mcycle	0%	0%	0%	0%	0%
	Rail	0%	0%	0%	0%	0%
Total		0%	0%	0%	0%	0%

Table 5-16 Travel demand comparison by time period by mode between RS 2041 and BAU 2041

#### ***5.4.1.1 Travel demand relating to the subcentres***

Table 5-17 shows the all the trips going to subcentres and the rest of the study area. When compare RS 2041 to BAU 2041, the results show that the increases in population and households in the four subcentres leads to the increases in flows in these areas. On the contrary, the decreases in population and households in the rest of the study areas means less trips will be made to and from these areas. However, the changes, mostly -1% to 0%, are not very significant. The overall changes are modest with the biggest change being the 12% increase in HBO trips by motorcycle.

BAU 2041							RS 2041			
AgDt	AgFl	AgUM	Average distance	Average cost	Average time	FlowVol.	Trip-km	Change in FlowVol.	Change in average distance	Change in Trip-km
The rest	HBW	Car	9.4	47.0	28.0	1,524,200	14,321,170	-1%	0%	-1%
		Bus	8.7	0.0	56.4	224,045	1,952,062	-1%	0%	-1%
		Walk	2.0	0.0	27.6	170,111	337,028	-1%	0%	-1%
		Cycle	6.0	0.0	33.2	134,332	801,188	-1%	0%	-1%
		Mcycle	5.9	12.3	24.6	2,870,800	16,880,821	-1%	0%	-1%
		Rail	8.7	26.1	8.8	33,461	342,201	-1%	0%	0%
Subcenters	HBW	Car	11.0	54.6	30.6	146,302	1,615,608	10%	-1%	3%
		Bus	10.9	0.0	64.0	21,104	229,429	3%	0%	3%
		Walk	1.7	0.0	24.6	14,730	24,375	12%	-1%	11%
		Cycle	7.1	0.0	36.9	12,836	31,251	10%	-1%	10%
		Mcycle	6.7	14.2	26.9	284,843	1,918,139	11%	-1%	3%
		Rail	13.7	32.8	10.1	3,412	46,881	6%	0%	5%
The rest	HBE	Car	4.1	23.2	21.3	512,377	2,034,680	-1%	0%	-1%
		Bus	7.9	0.0	54.8	463,788	3,644,296	-1%	0%	-1%
		Walk	1.8	0.0	25.7	447,534	814,734	-1%	0%	-1%
		Cycle	5.4	0.0	30.2	254,319	1,363,112	-1%	0%	-1%
		Mcycle	4.7	10.7	22.2	1,089,500	5,171,987	-1%	0%	-1%
		Rail	8.0	25.0	3.1	24,430	195,775	-1%	0%	0%
Subcenters	HBE	Car	4.5	26.8	23.5	52,500	237,791	11%	-2%	8%
		Bus	9.1	0.0	59.8	52,416	478,858	3%	-1%	8%
		Walk	1.6	0.0	23.7	50,685	82,471	13%	-1%	12%
		Cycle	5.9	0.0	31.5	30,022	178,120	10%	-2%	8%
		Mcycle	5.1	11.5	23.1	123,943	628,029	11%	-2%	8%
		Rail	12.3	30.2	10.4	1,982	24,362	7%	-1%	6%
The rest	HBO	Car	4.5	19.1	22.6	473,570	2,138,314	-1%	0%	-1%
		Bus	6.2	0.0	48.8	134,931	837,620	-1%	0%	0%
		Walk	1.8	0.0	26.0	271,091	501,495	-1%	0%	-1%
		Cycle	4.1	0.0	25.2	140,431	581,438	-1%	0%	-1%
		Mcycle	3.7	7.3	19.0	1,515,800	5,556,802	-1%	0%	-1%
		Rail	7.4	24.3	8.8	13,417	99,058	-1%	0%	-1%
Subcenters	HBO	Car	5.0	21.7	24.2	44,854	226,103	11%	-1%	10%
		Bus	7.5	0.0	54.1	12,423	93,432	11%	0%	10%
		Walk	1.6	0.0	23.0	28,082	44,189	12%	-1%	12%
		Cycle	4.4	0.0	25.1	14,384	62,678	12%	-1%	10%
		Mcycle	3.8	7.5	18.9	157,310	590,348	12%	-1%	11%
		Rail	11.6	23.1	10.0	737	3,212	7%	0%	7%
The rest	NHB	Car	6.2	24.0	24.6	309,041	1,913,994	-1%	0%	-1%
		Bus	7.8	0.0	53.9	225,135	1,752,615	-1%	0%	0%
		Walk	1.9	0.0	26.6	130,698	248,509	-1%	0%	-1%
		Cycle	5.3	0.0	30.1	76,759	404,112	-1%	0%	-1%
		Mcycle	5.5	10.8	24.5	338,788	1,868,140	-1%	0%	-1%
		Rail	8.0	25.1	8.9	3,020	72,223	-1%	1%	0%
Subcenters	NHB	Car	7.0	27.4	26.5	28,155	197,019	10%	-1%	3%
		Bus	9.6	0.0	61.0	21,471	206,304	11%	0%	10%
		Walk	1.6	0.0	23.6	12,543	20,269	12%	-1%	11%
		Cycle	6.1	0.0	32.7	7,587	46,451	11%	-1%	10%
		Mcycle	6.1	11.9	26.0	33,106	200,817	11%	-1%	10%
		Rail	12.8	31.2	10.1	708	3,058	7%	0%	7%
The rest	NMKT	Car	3.4	14.7	20.6	142,642	481,050	0%	0%	0%
		Bus	5.9	0.0	48.5	150,375	889,309	0%	0%	0%
		Walk	1.2	0.0	18.4	147,530	180,874	0%	0%	0%
		Cycle	3.0	0.0	19.8	50,184	148,976	0%	0%	0%
		Mcycle	2.9	5.8	16.3	262,929	758,180	0%	0%	0%
		Rail	7.4	24.4	8.8	2,763	20,518	0%	0%	0%
Subcenters	NMKT	Car	3.1	16.1	22.1	12,105	36,322	2%	0%	2%
		Bus	6.1	0.0	50.8	11,848	72,136	2%	0%	2%
		Walk	1.0	0.0	15.8	17,431	17,440	2%	0%	2%
		Cycle	2.6	0.0	17.7	5,350	13,802	2%	0%	2%
		Mcycle	2.5	5.0	14.6	29,023	71,224	2%	0%	2%
		Rail	12.5	30.8	10.2	143	1,796	1%	0%	1%

Table 5-17 Comparison of travel demand by activity by mode: BAU 2041 vs RS 2041

Figure 5-36 the trips going to one of the zones in the subcentre, Shalu, which experience the greatest change. The magnitude of changes is modest with most of the changes is under 25%. Figure 5-37 shows the number of flows drawn to this zone from each one of the rest of the zones in absolute terms under the RS 2041 scenario. The number of flows generated from the zones further away from zone 49 are mostly under 100.

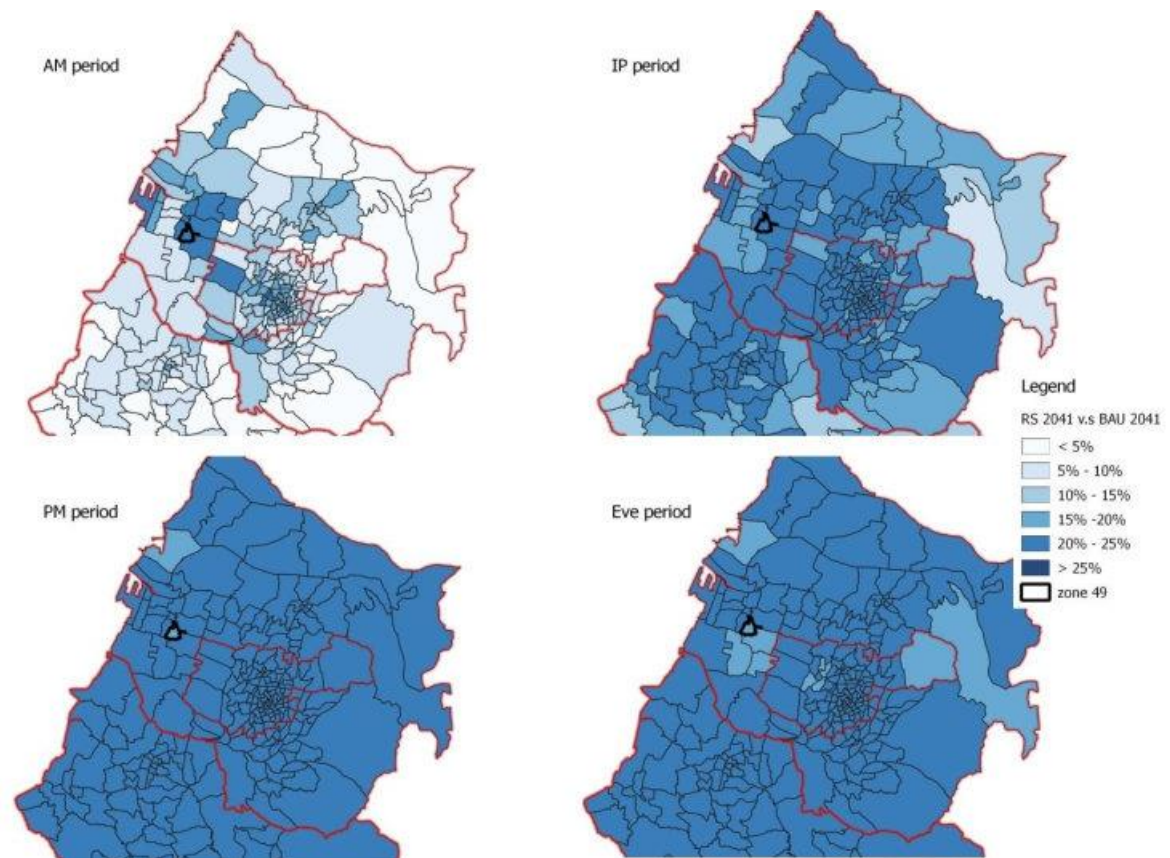


Figure 5-36 Comparison of passenger trip volume to destination zone 49

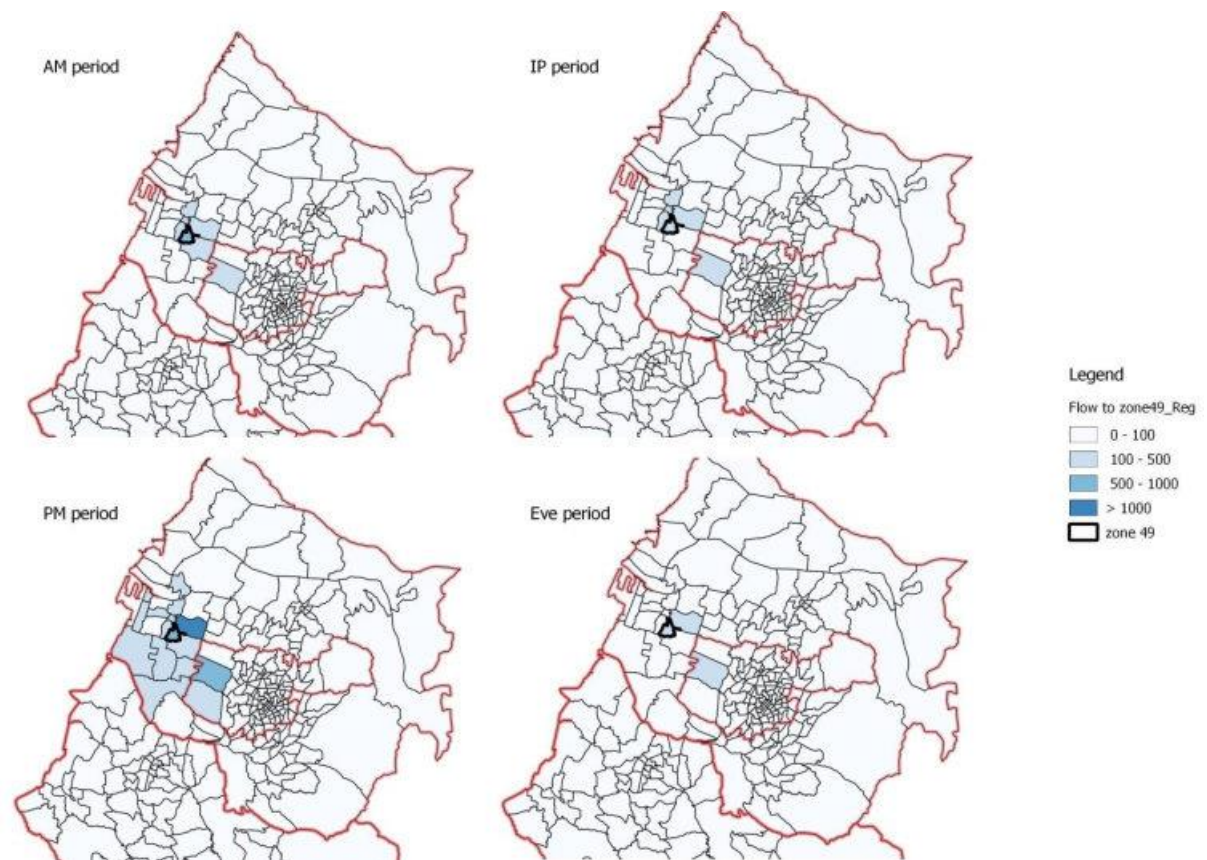


Figure 5-37 Passenger trip volume to destination zone 49 under RS 2041



#### 5.4.2 Link traffic volumes under RS 2041

Figure 5-38 to Figure 5-43 show the capacity ratio for each link for each peak hour for RS 2041 scenario. As expected, because the dispersed subcentres and the relatively small changes in travel demand, the patterns do not change very much from those of BAU 2041 scenario.

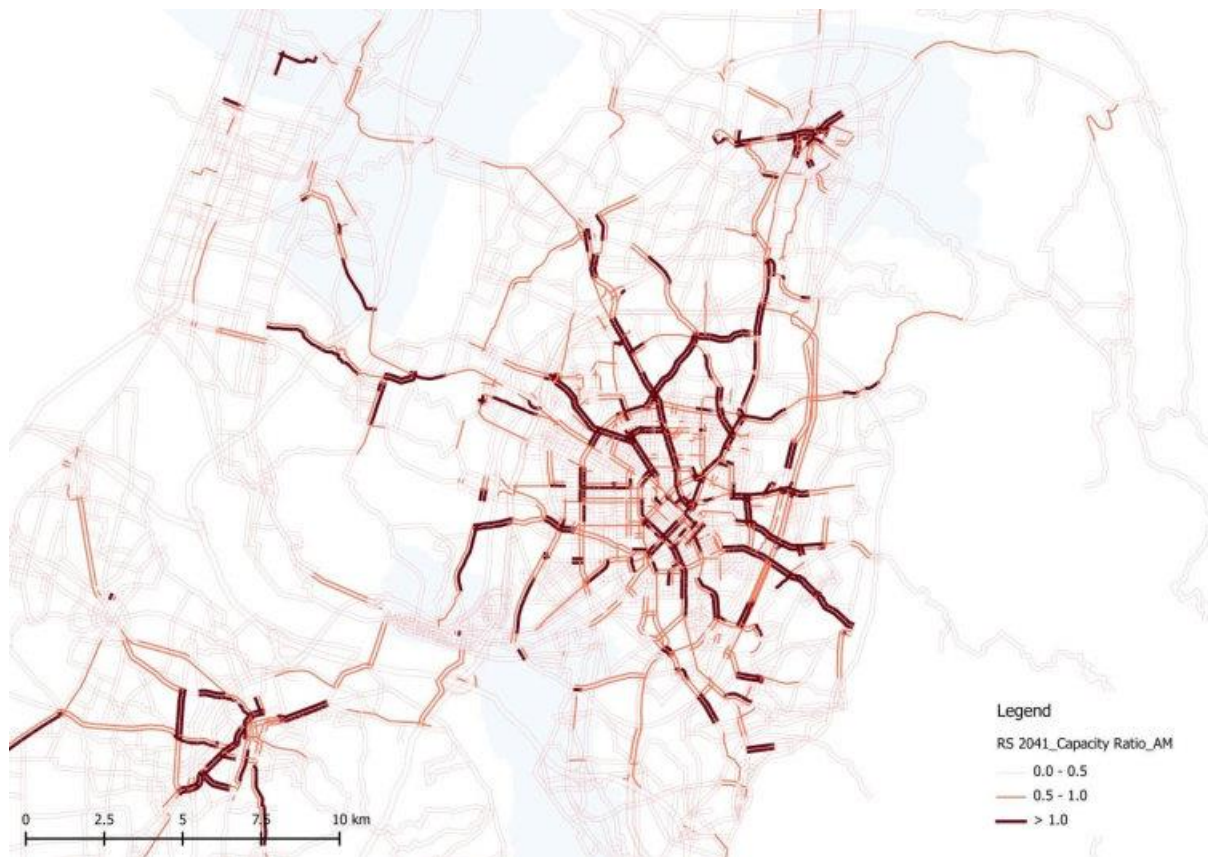


Figure 5-38 Link load/capacity ratio in AM peak hour for RS 2041

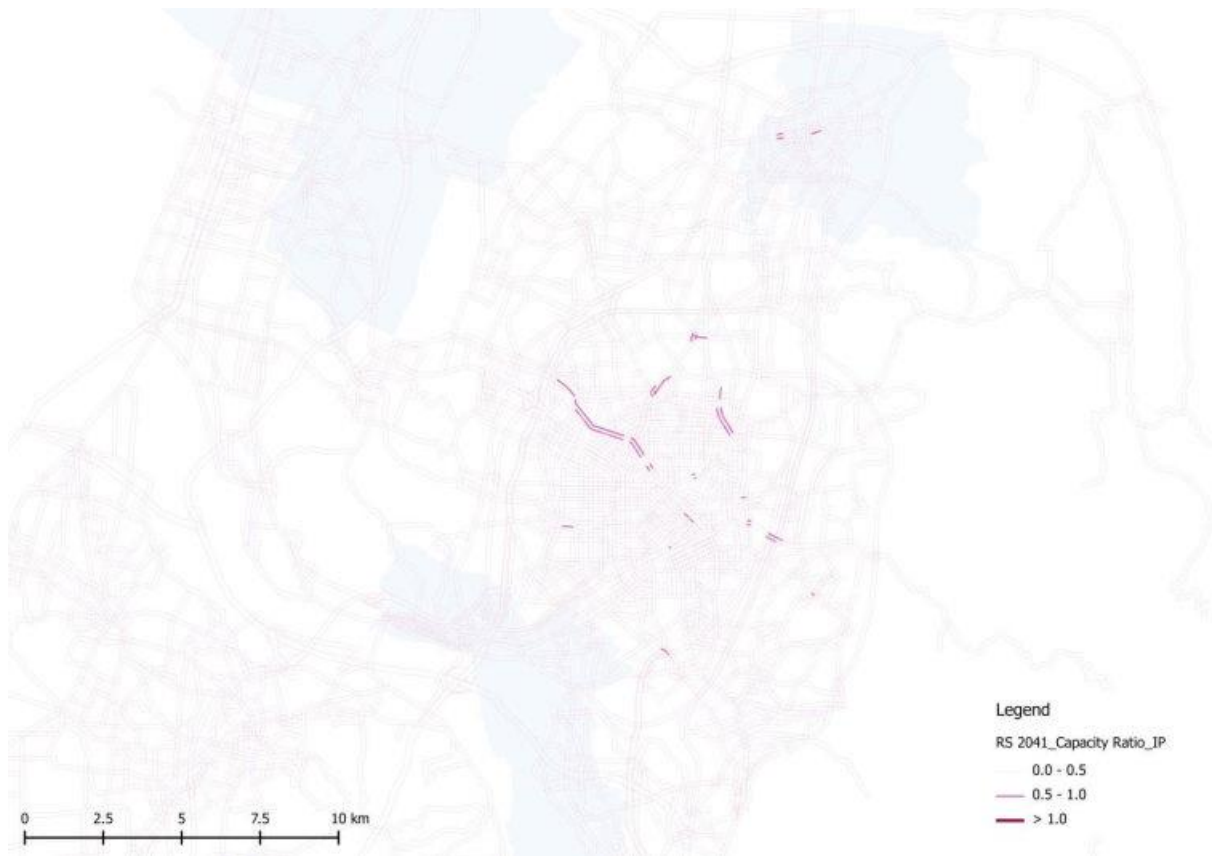


Figure 5-39 Link load/capacity ratio in Interpeak hour for RS 2041

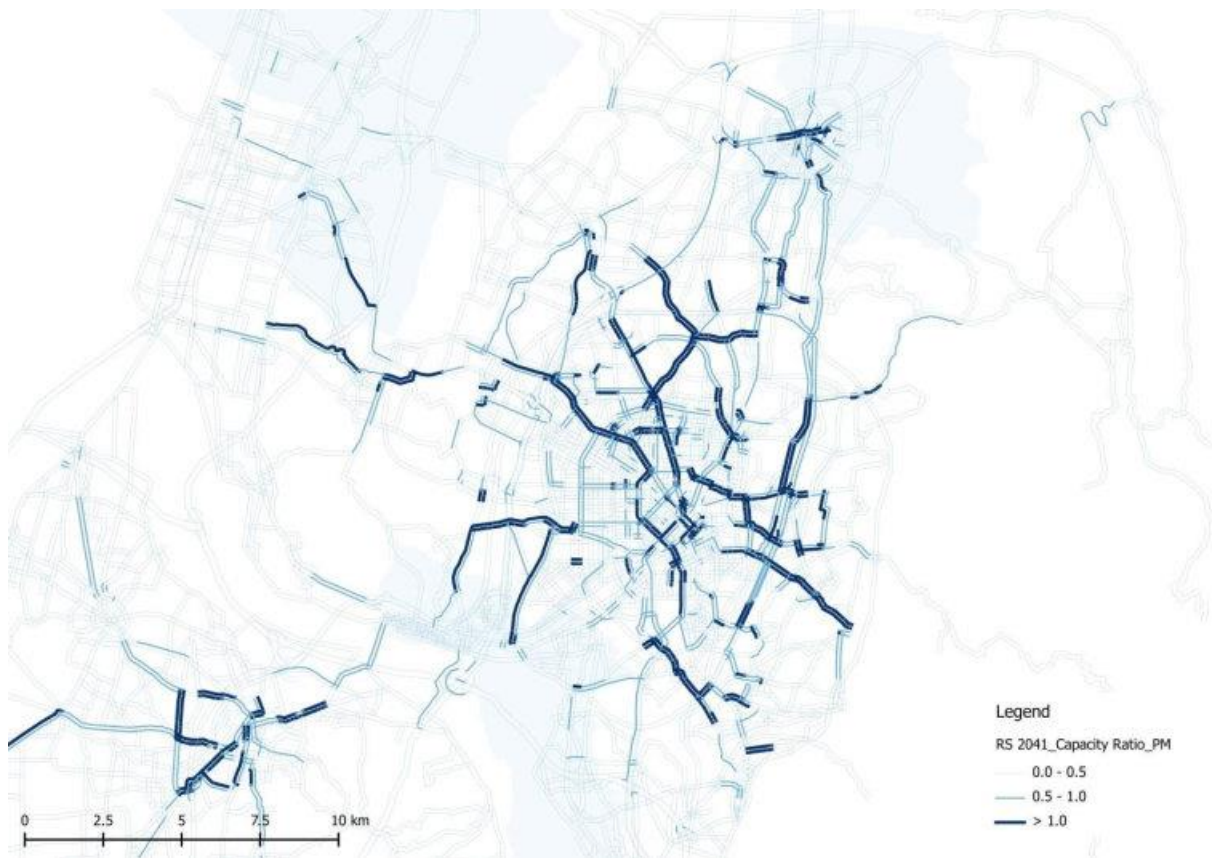


Figure 5-40 Link load/capacity ratio in PM peak hour for RS 2041

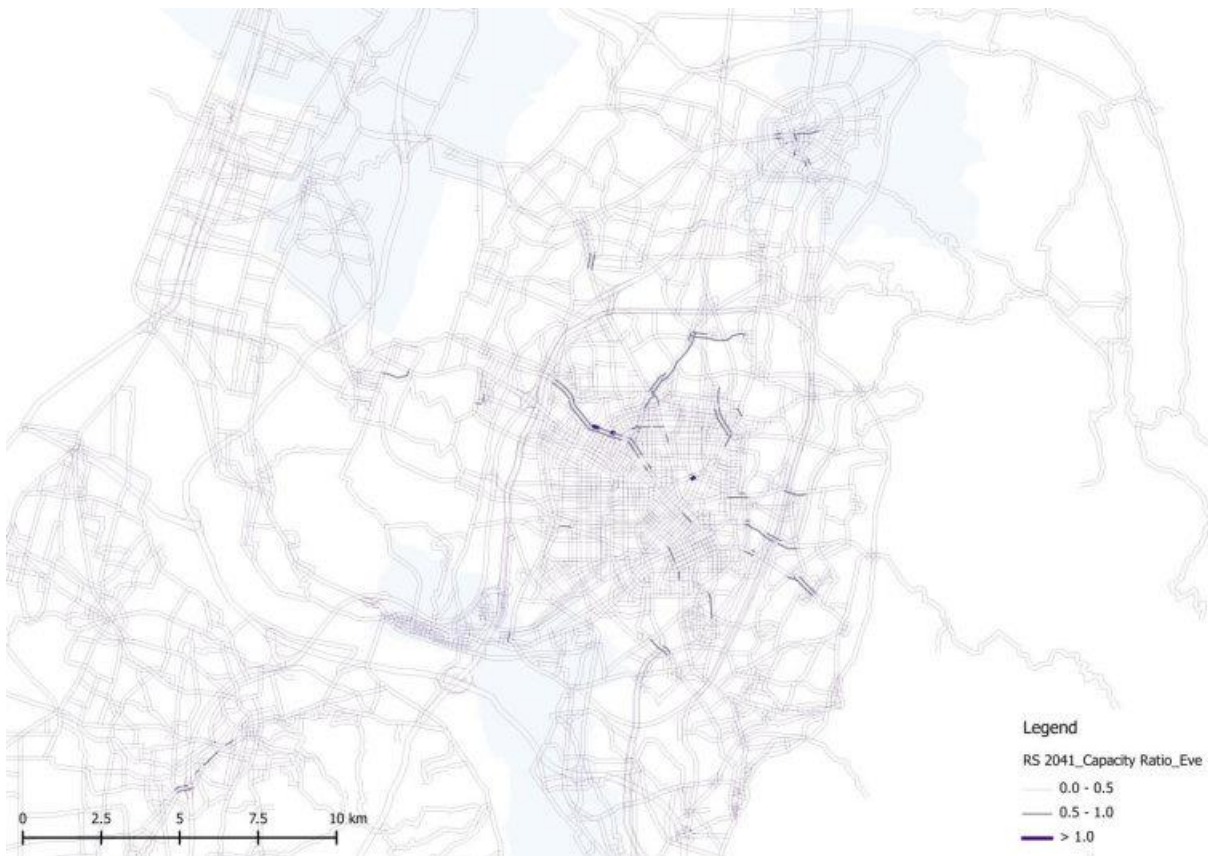


Figure 5-41 Link load/capacity ratio in Evening peak hour for RS 2041

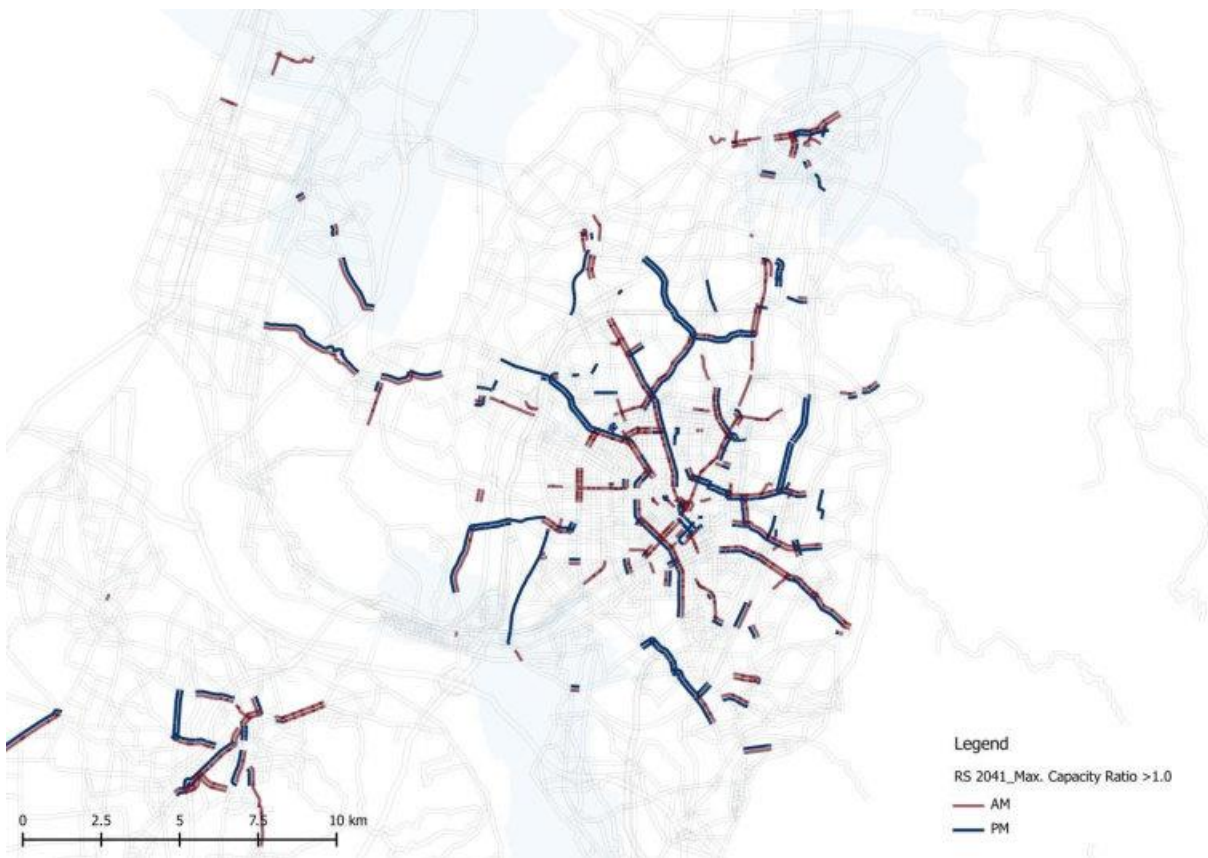


Figure 5-42 Maximum link load/capacity ratio > 1 by peak hour for RS 2041



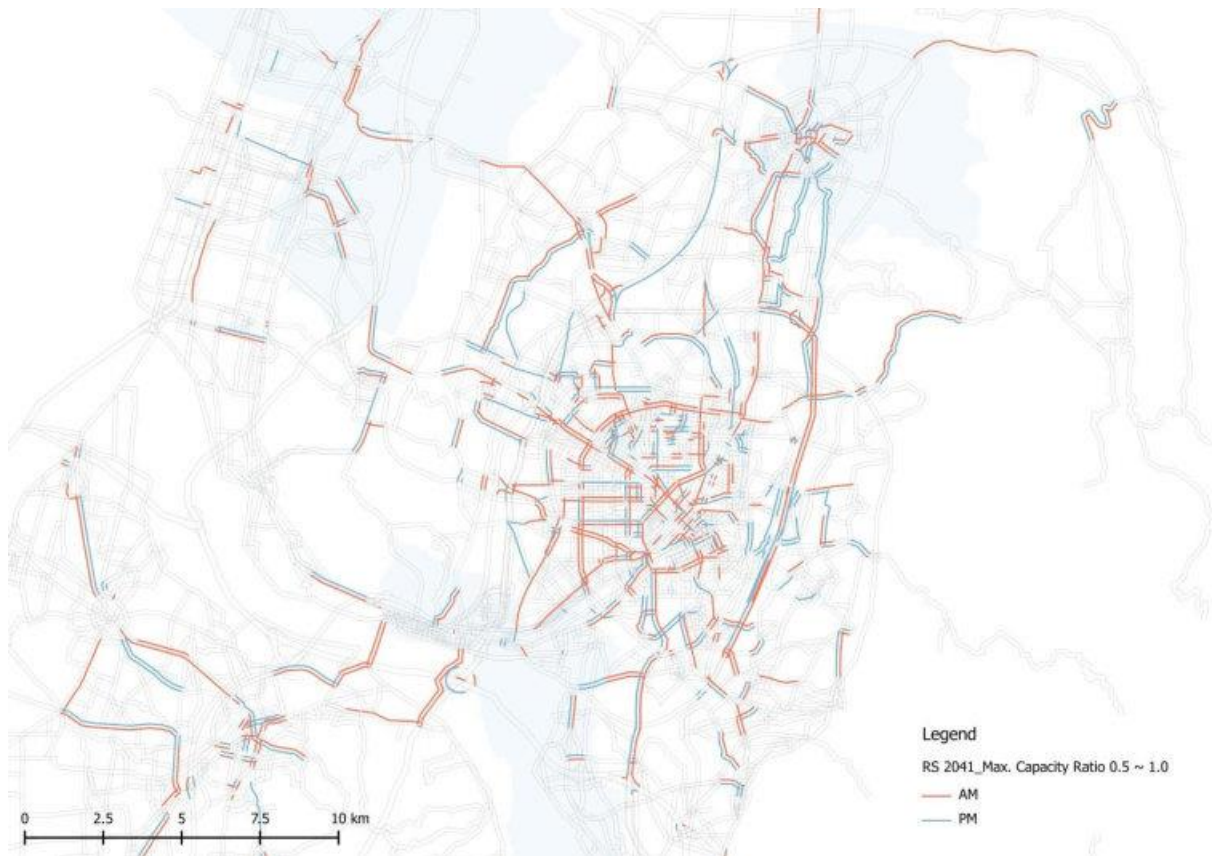


Figure 5-43 Maximum link load/capacity ratio between 0.5 and 1 by peak hour for RS 2041

#### 5.4.3 Link traffic volumes comparison between RS 2041 and BAU 2041

Figure 5-44 to Figure 5-47 show the comparison between BAU 2041 scenario and RS 2041 scenario. The changes are of less magnitude with the links of the most change being between -10% and 10%. There is no single link which experience flow reduction over 10%. This is because the subcentres are assumed to have only changes in the number of household and population instead of having any increased attractiveness of activities to divert the distribution of travel demand from other areas in Taichung. This can also explain the increase in traffic flow to the western district, Shalu. Because its assumed change in the number of the households is largest among all the subcentres, a 56% increase, therefore the links experiencing noticeable increase in traffic flow under RS 2041 scenario are mostly the ones near this district.

Figure 5-49 highlights the links with increased hourly maximum flow between RS 2041 and BAU 2041. The following four figures, Figure 5-50 to Figure 5-53, show the period traffic flow under this circumstance.



Figure 5-44 Link flow change between RS 2041 and BAU 2041 in AM peak hour



Figure 5-45 Link flow change between RS 2041 and BAU 2041 in Interpeak hour





Figure 5-46 Link flow change between RS 2041 and BAU 2041 in PM peak hour

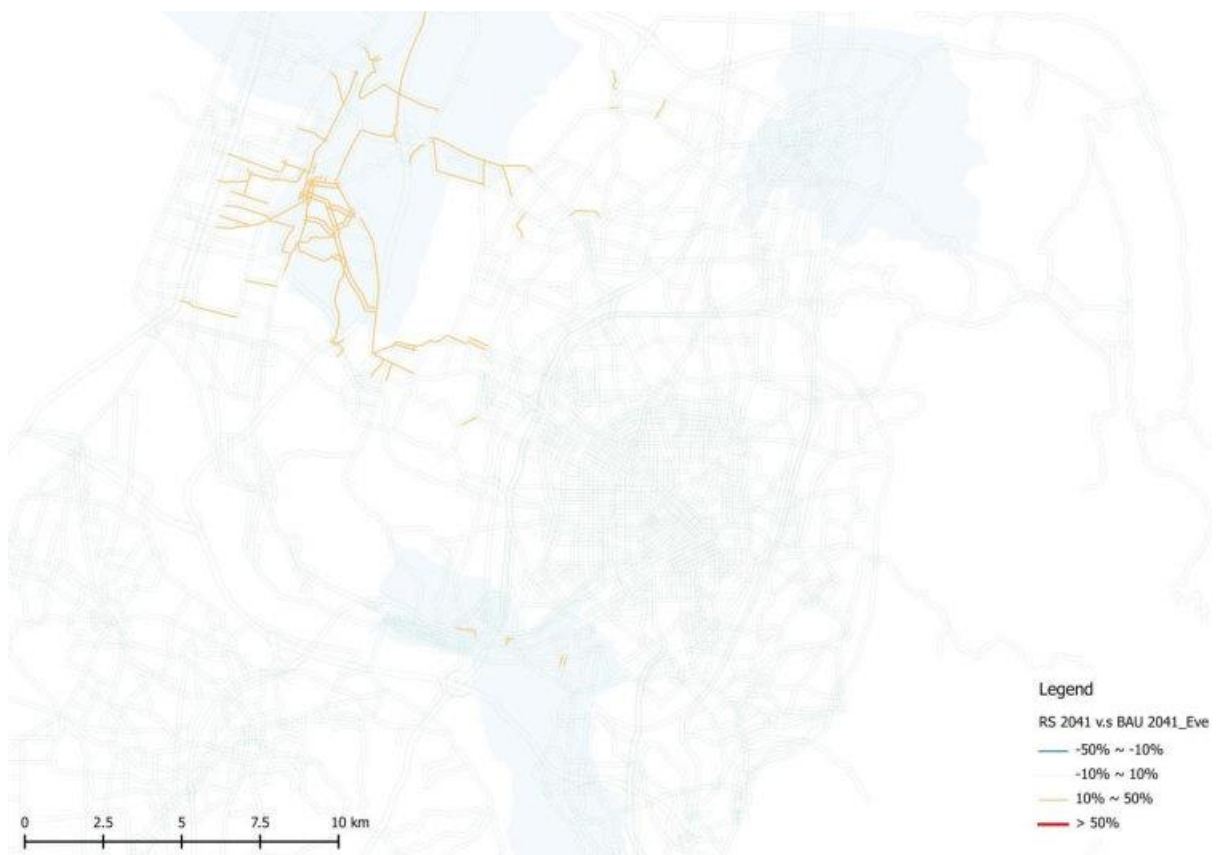


Figure 5-47 Link flow change between RS 2041 and BAU 2041 in Evening peak hour

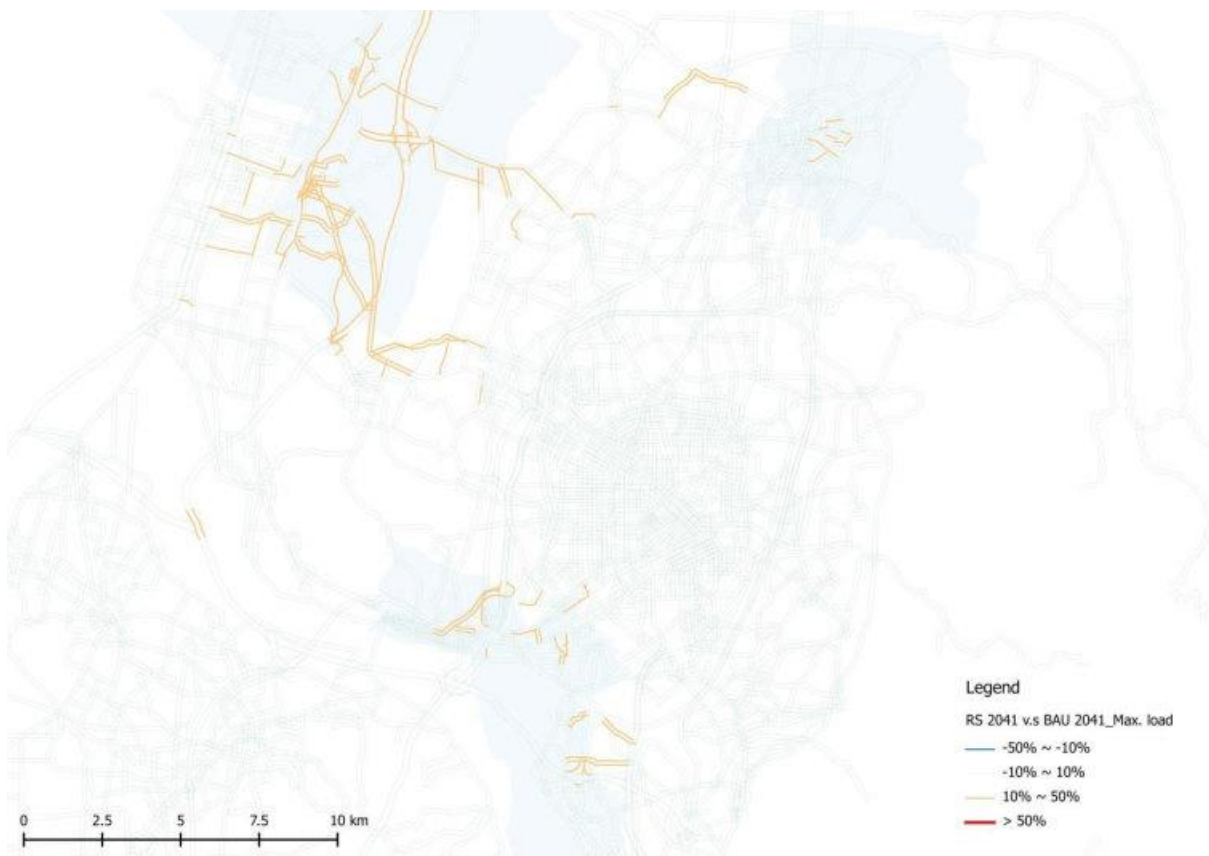


Figure 5-48 Maximum link flow change between RS 2041 and BAU 2041

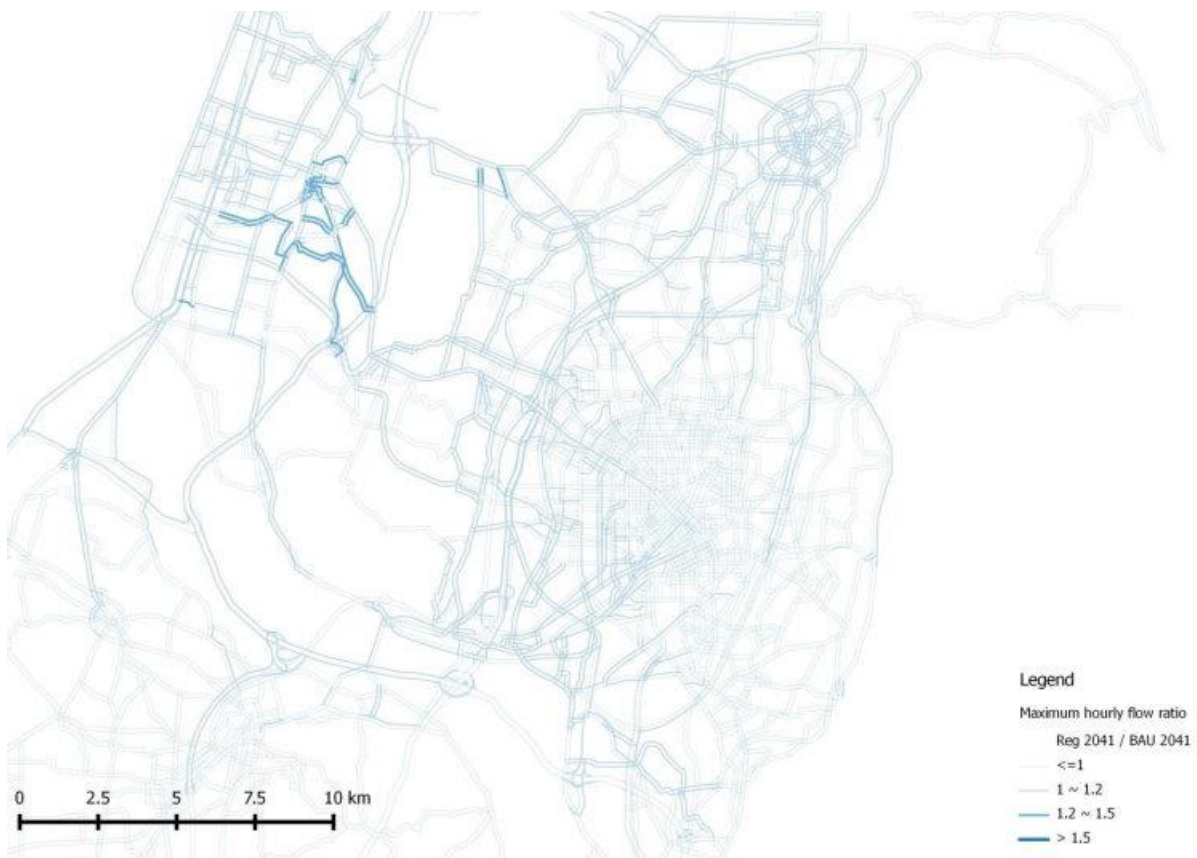


Figure 5-49 Ratio of maximum hourly link flow between RS 2041 and BAU 2041

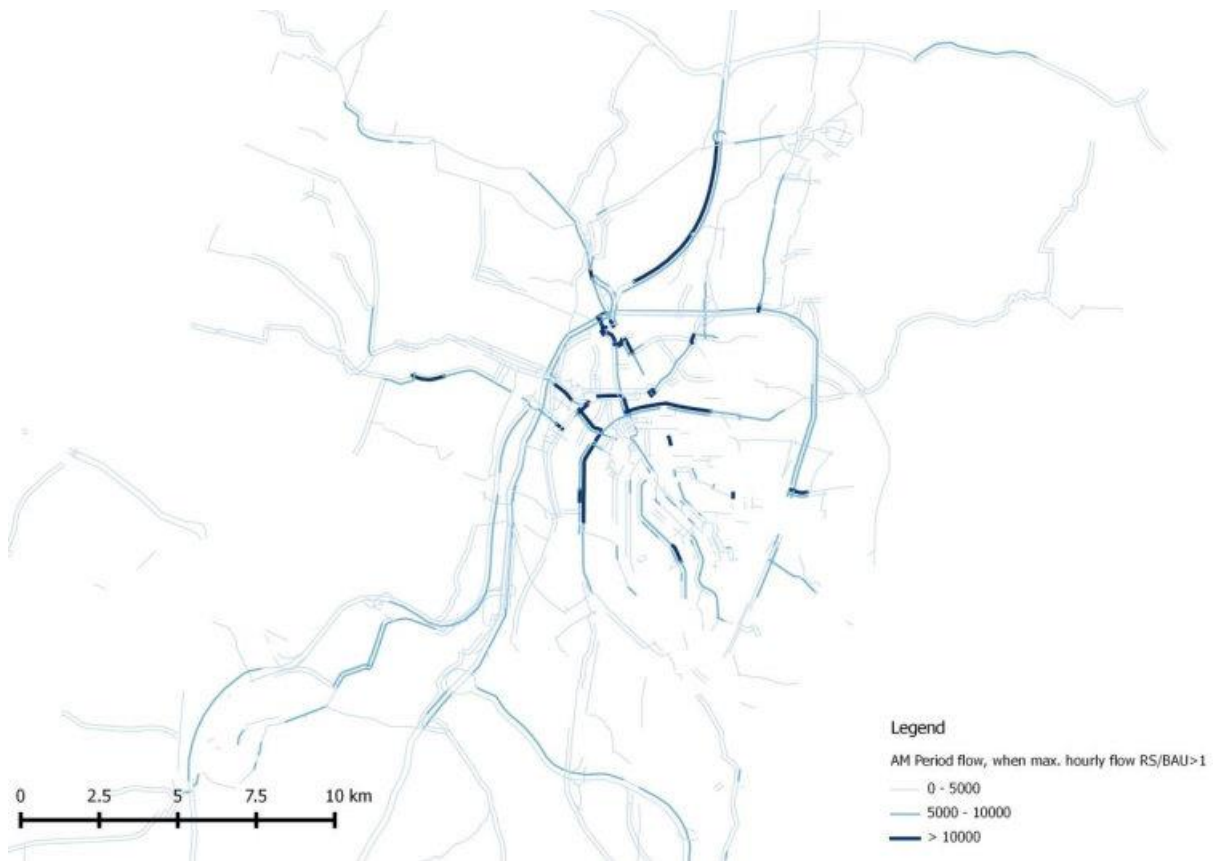


Figure 5-50 AM period flow when maximum hourly link flow RS 2041 > BAU 2041

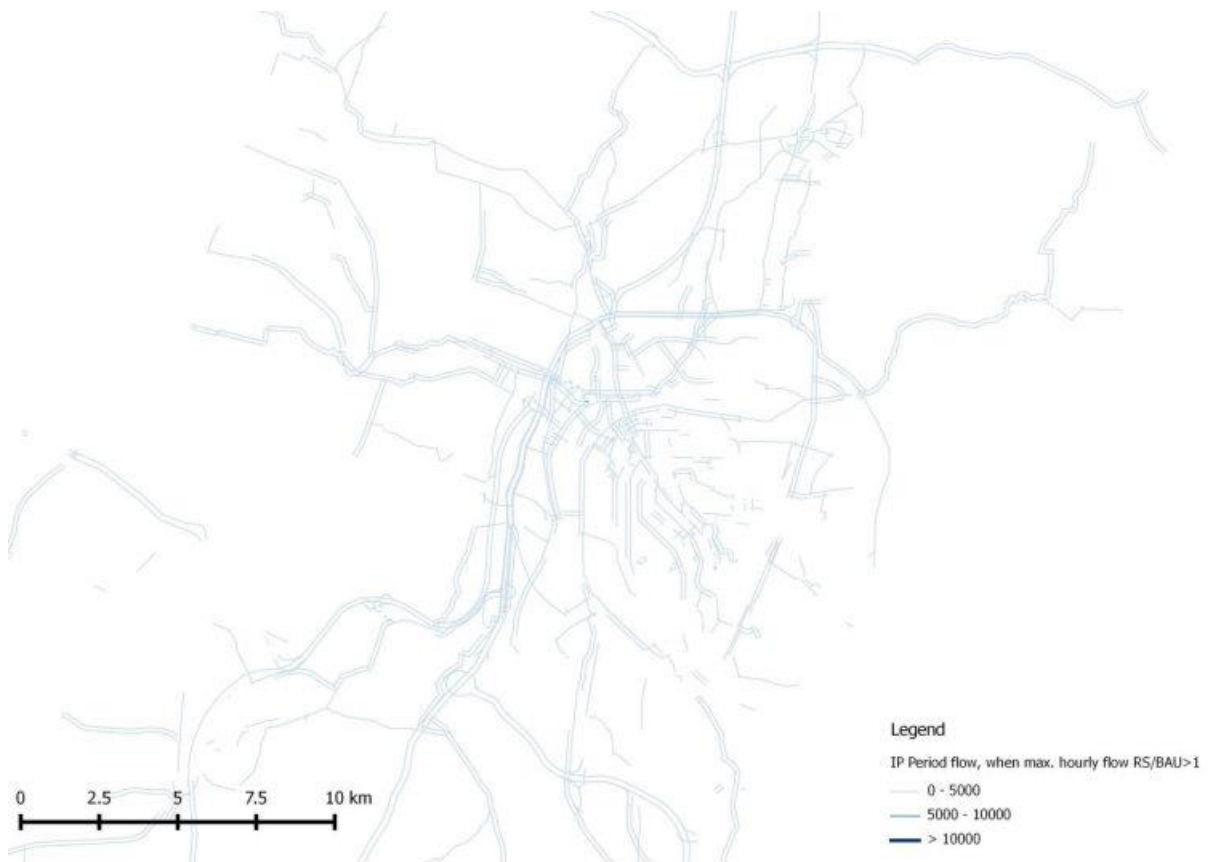


Figure 5-51 Inter peak period flow when maximum hourly link flow RS 2041 > BAU 2041

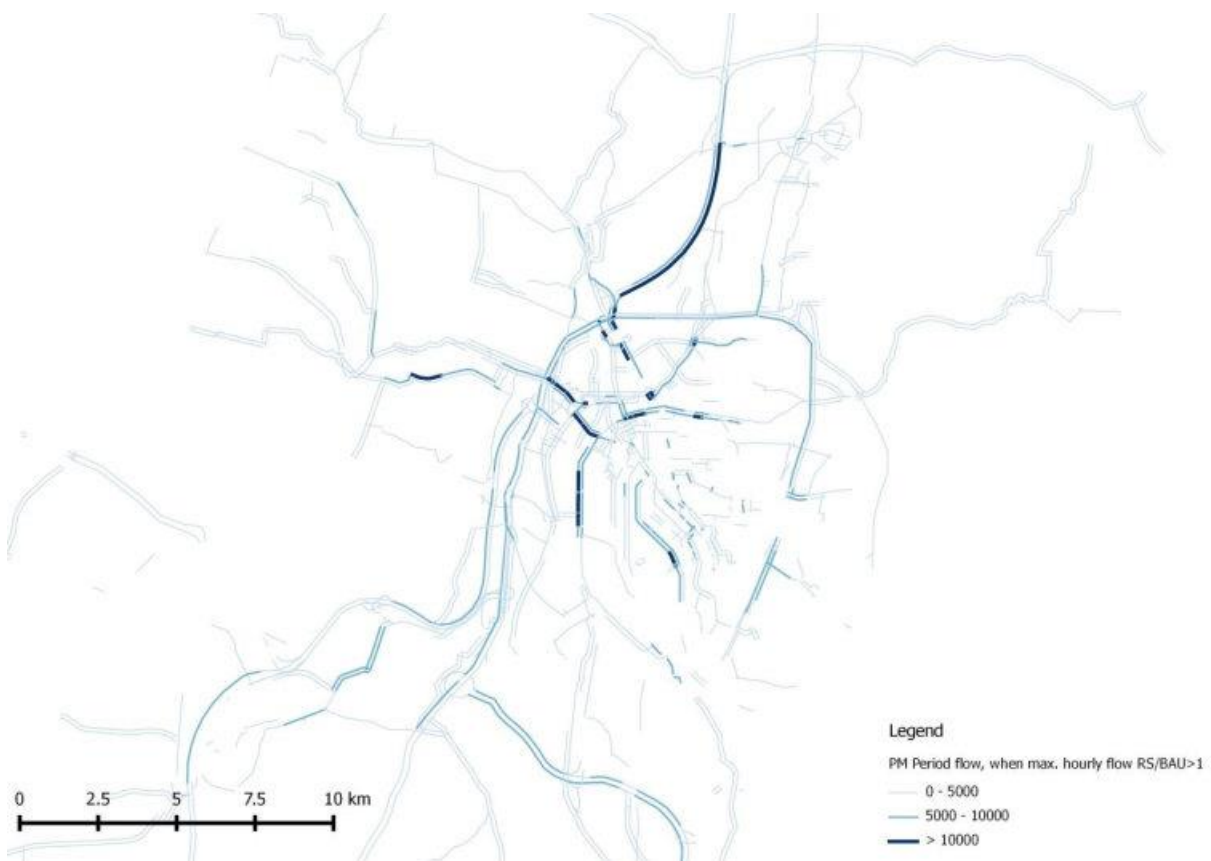


Figure 5-52 PM period flow when maximum hourly link flow RS 2041 > BAU 2041

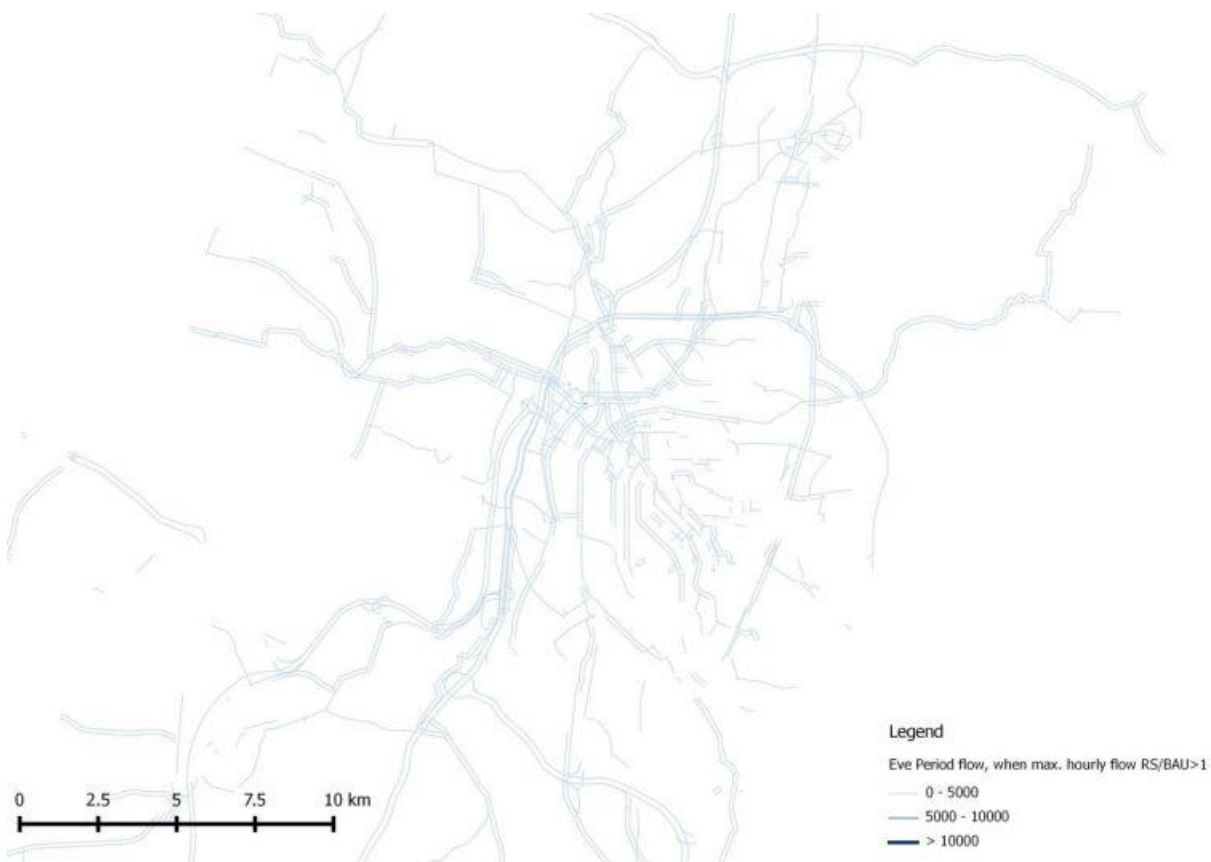


Figure 5-53 Evening period flow when maximum hourly link flow RS 2041 > BAU 2041



Figure 5-54 shows link entropy between BAU 2041 and RS 2041 scenario when the maximum hourly flows on a link experience an increase under the RS 2041 scenario. The weighted average entropy for RS 2041 being 1.2115. The fluctuation in flows do not change much between the two scenarios.

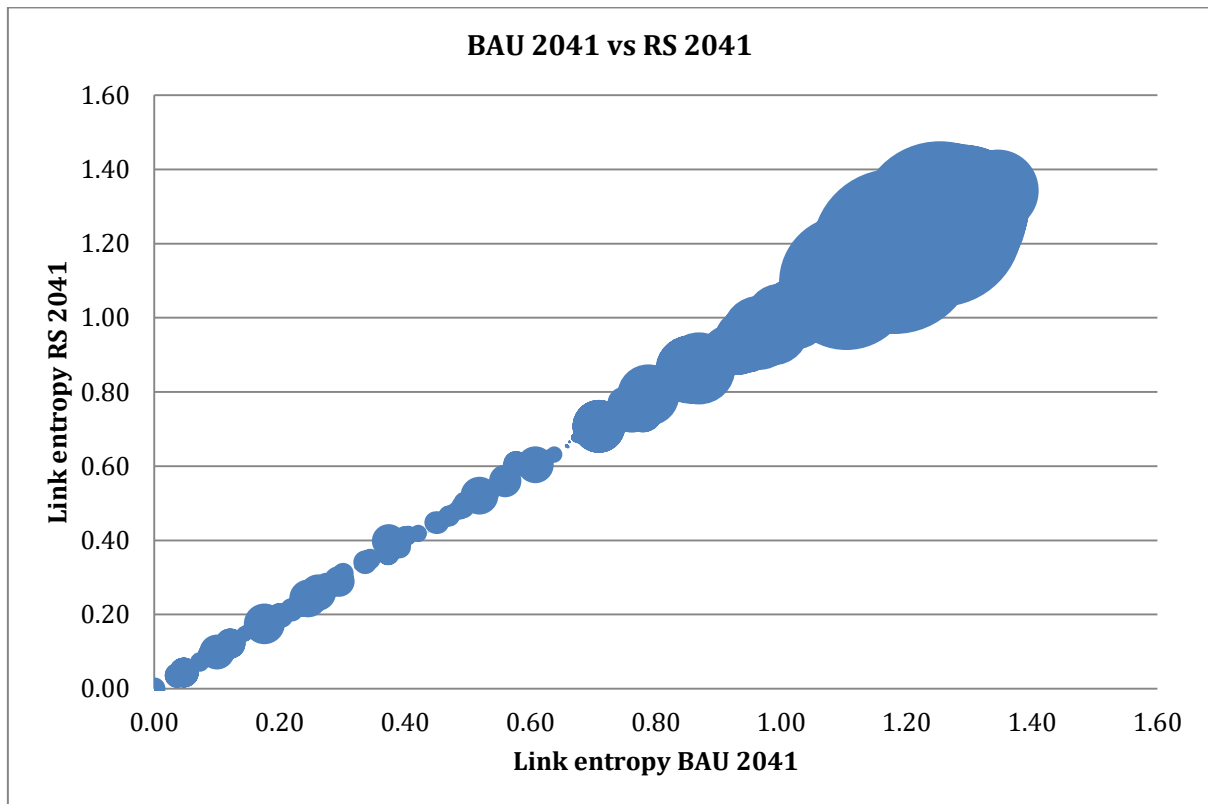


Figure 5-54 Link entropy between BAU 2041 and RS 2041 scenario

## 5.5 Sensitivity analysis

In this section the sensitivity analysis has been undertaken to further validate the model's fitness for purpose.

The concentration parameters (values of base run in Table 4-4 and Table 4-5 and Table 4-24) are first chosen for sensitivity analysis in order to cover the uncertainties in the estimation of the discrete choice models. The values of parameters are respectively increased and decreased by 25%. The resultant weighted entropy for each scenario is summarised in Table 5-18 below. The weighted entropy values across all cases remain around 1.2. When the concentration parameters are increased by 25%, the entropy for all the scenarios decrease, although only slightly and the order of the values do not change, i.e. the Existing 2013 scenario being with the highest entropy, followed by BAU 2041, RS 2041 and RaSnAS 2041. When the concentration parameters are decreased by 25%, the entropy for all the scenarios increase, although only slightly. And again, the order of the

value do not change. Figure 5-55 to Figure 5-60 show the link entropy comparison between scenarios. Figure 5-14 Link entropy between Existing 2013 and BAU 2041 scenario, Figure 5-55 and Figure 5-58 show similar pattern for the comparison between Existing 2013 and BAU 2041 scenario. Similar patterns are observed in Figure 5-34, Figure 5-56 and Figure 5-59. So are in Figure 5-54 Link entropy between BAU 2041 and RS 2041 scenario, Figure 5-57 and Figure 5-60. This confirms that the general behaviour of the model do not change.

Scenario	Existing 2013	BAU 2041	RaSnAS 2041	RS 2041
Base run	1.2134	1.2120	1.2067	1.2115
Concentration parameters increased by 25%	1.2121	1.2089	1.2039	1.2083
Concentration parameters decreased by 25%	1.2157	1.2137	1.2083	1.2133

Table 5-18 Weighted link entropy comparison with changes in concentration parameters

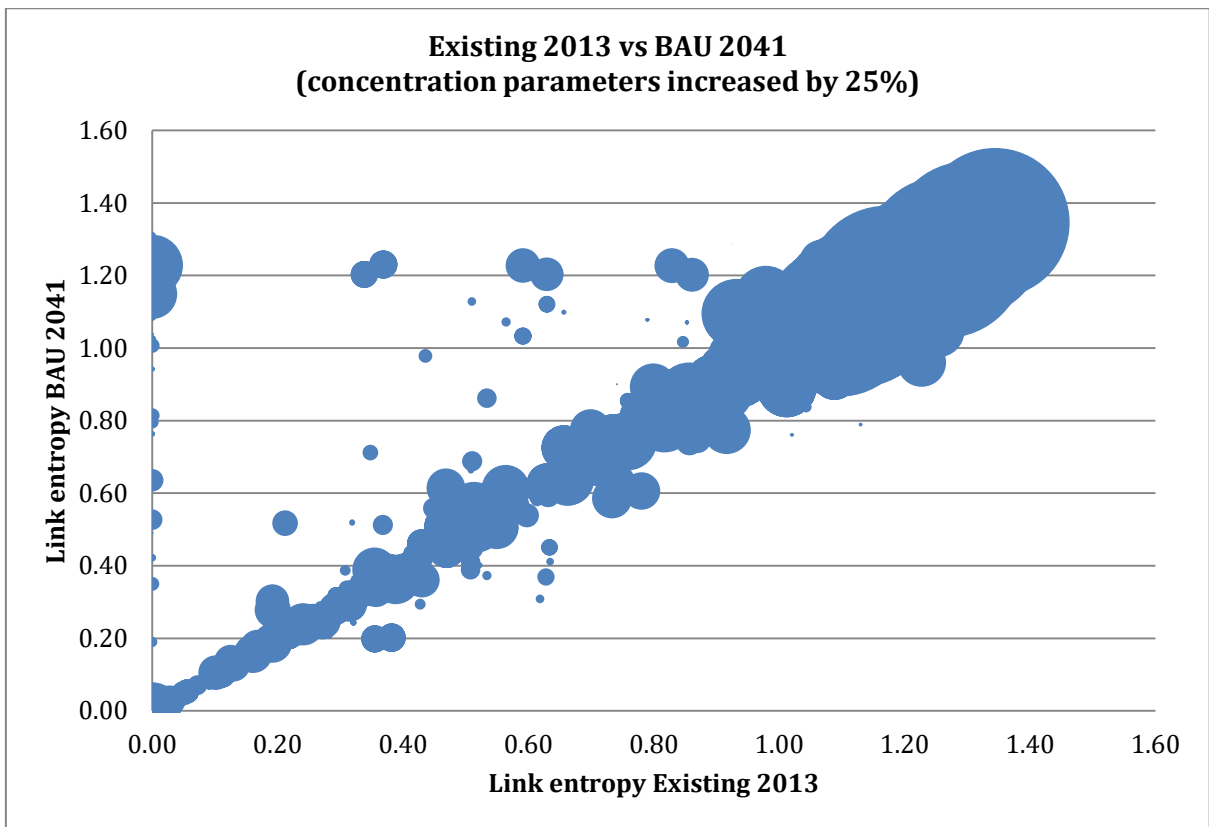


Figure 5-55 Link entropy between Existing 2013 and BAU 2041 scenario, with concentration parameters increased by 25%

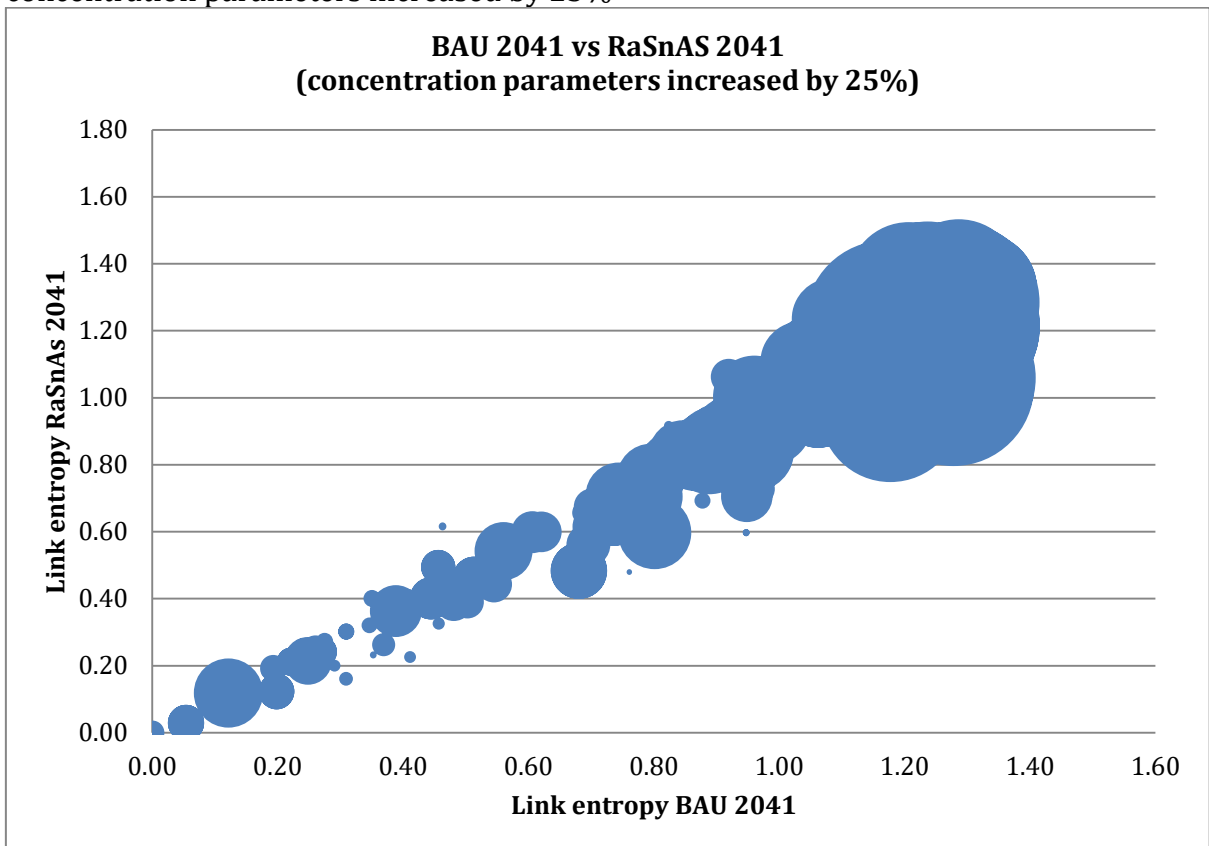


Figure 5-56 Link entropy between BAU 2041 and RaSnAS 2041 scenario, with concentration parameters increased by 25%

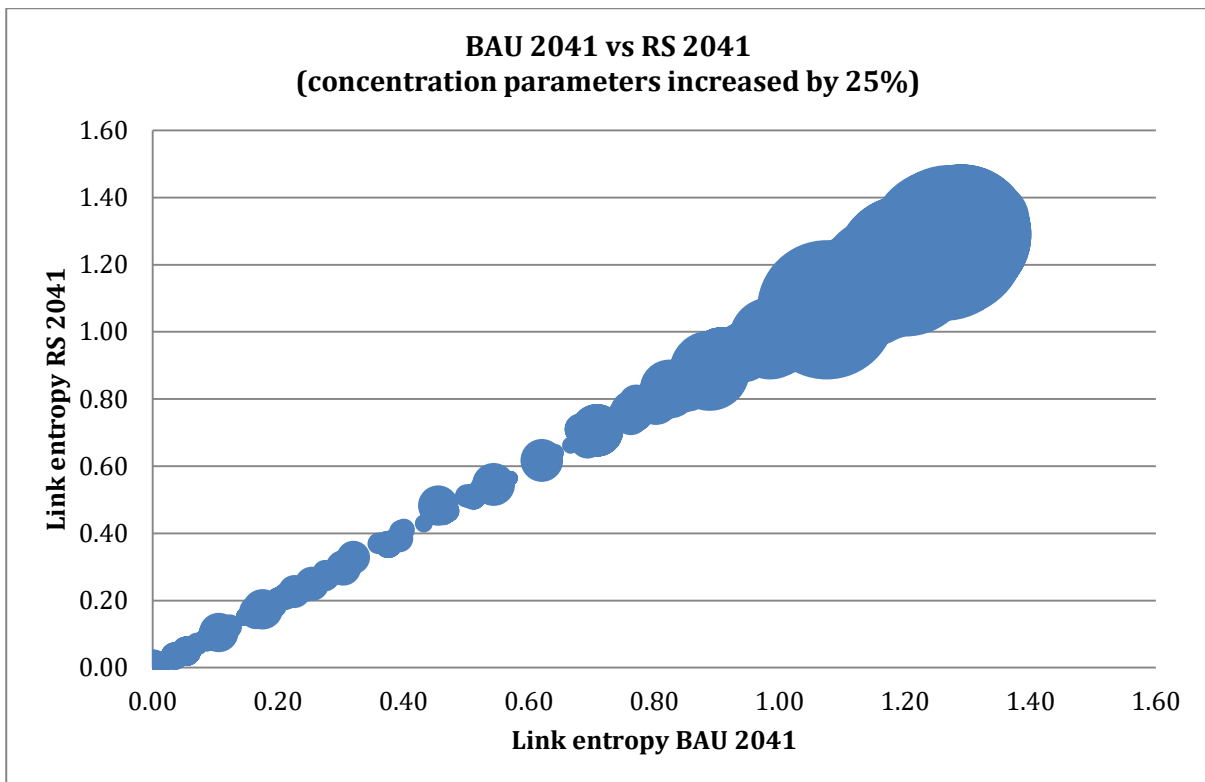


Figure 5-57 Link entropy between BAU 2041 and RS 2041 scenario, with concentration parameters increased by 25%

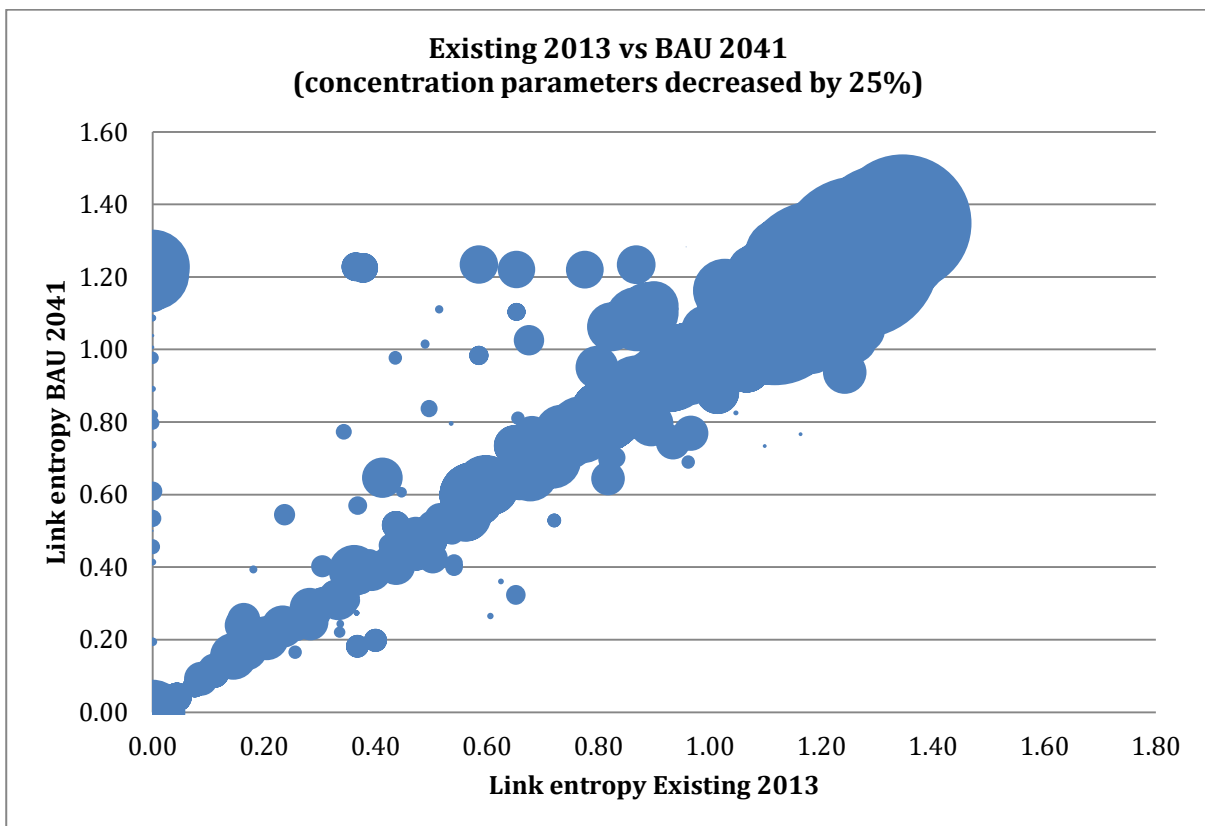


Figure 5-58 Link entropy between Existing 2013 and BAU 2041 scenario, with concentration parameters decreased by 25%



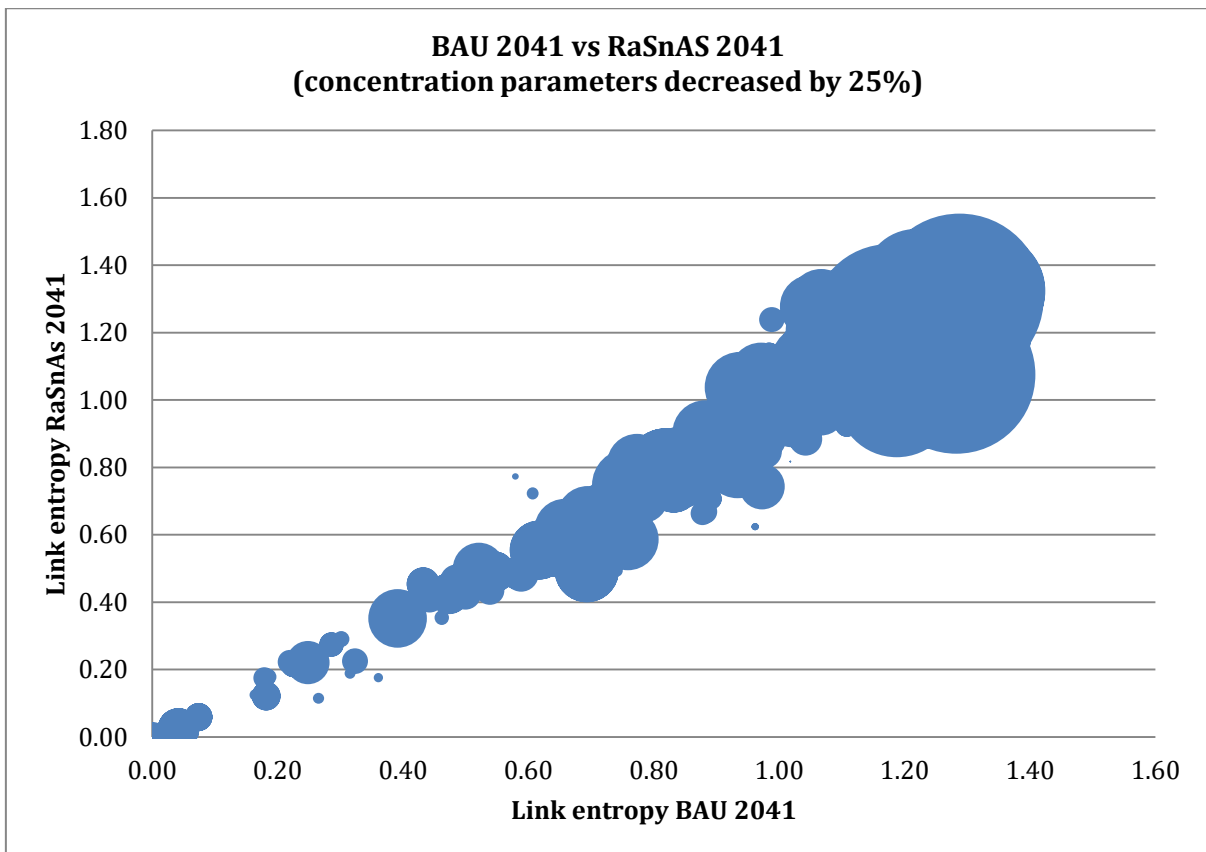


Figure 5-59 Link entropy between BAU 2041 and RaSnAS 2041 scenario, with concentration parameters decreased by 25%

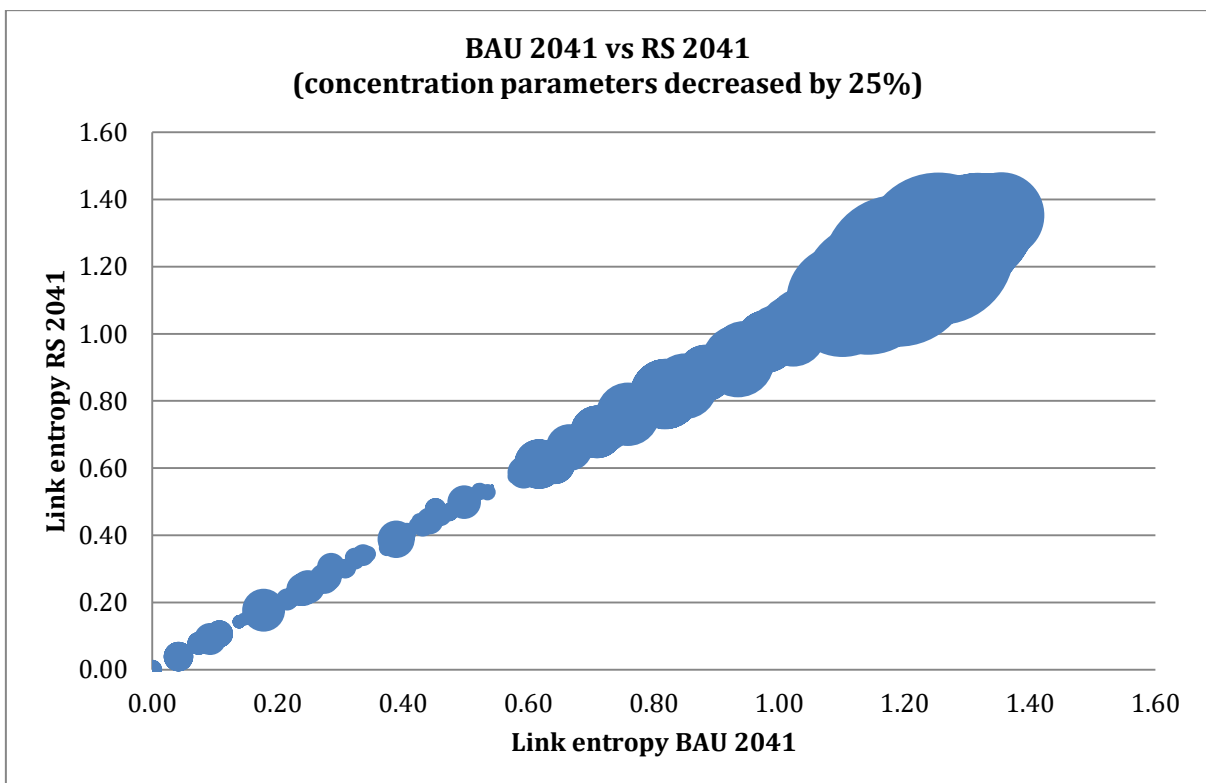


Figure 5-60 Link entropy between BAU 2041 and RS 2041 scenario, with concentration parameters decreased by 25%

A further set of parameters chosen for the sensitivity analysis are the demand coefficient for night market activities by tourists (term  $tt$  in Equation 3.12). It is chosen because of the uncertainties in the values adopted in the model. The demand coefficient in the base run is assumed to be 1. However, it is also possible that the tourists make less than one trip every day to the night markets when they visit Taichung. Therefore, in the sensitivity analysis, the demand coefficient have been set to 0.5.

The resultant weighted link entropy for each scenario is summarised in the table below. The weighted entropy values of all the scenarios remain around 1.2. When the demand coefficient changed to 0.5, the entropy for all the scenarios decrease, although only slightly and the order of the values do not change, i.e. the Existing 2013 scenario being with the highest entropy, followed by BAU 2041, RS 2041 and RaSnAS 2041.

Figure 5-61 to Figure 5-63 show the link entropy comparison between scenarios. Figure 5-14 Link entropy between Existing 2013 and BAU 2041 scenario and Figure 5-61 show similar pattern for the comparison between Existing 2013 and BAU 2041 scenario. Similar patterns are observed in Figure 5-34 and Figure 5-62. So are in Figure 5-54 Link entropy between BAU 2041 and RS 2041 scenario and Figure 5-63. This confirms that the general behaviour of the model do not change.

Scenario	Existing 2013	BAU 2041	RaSnAS 2041	RS 2041
Base run (demand coefficient set to 1)	1.2134	1.2120	1.2067	1.2115
Demand coefficient changed to 0.5	1.2132	1.2116	1.1977	1.2101

Table 5-19 Weighted link entropy comparison with change in demand coefficient

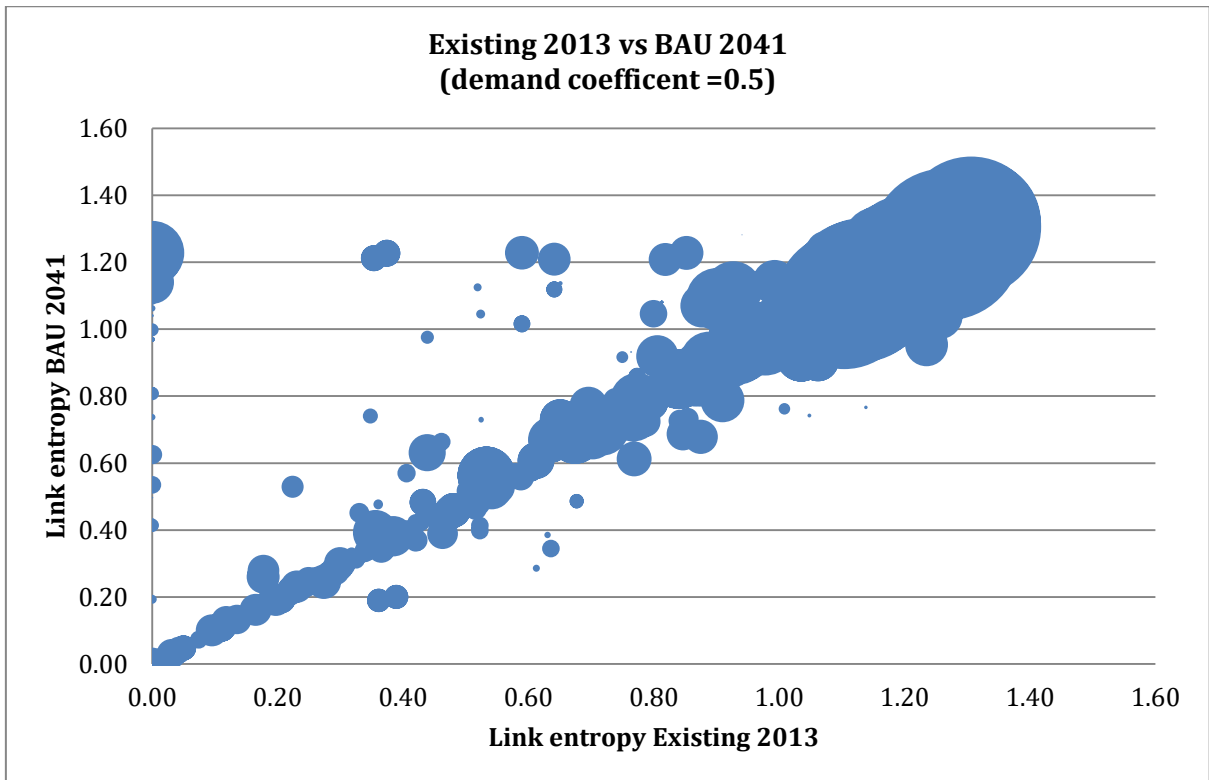


Figure 5-61 Link entropy between Existing 2013 and BAU 2041 scenario, with demand coefficient decreased to 0.5

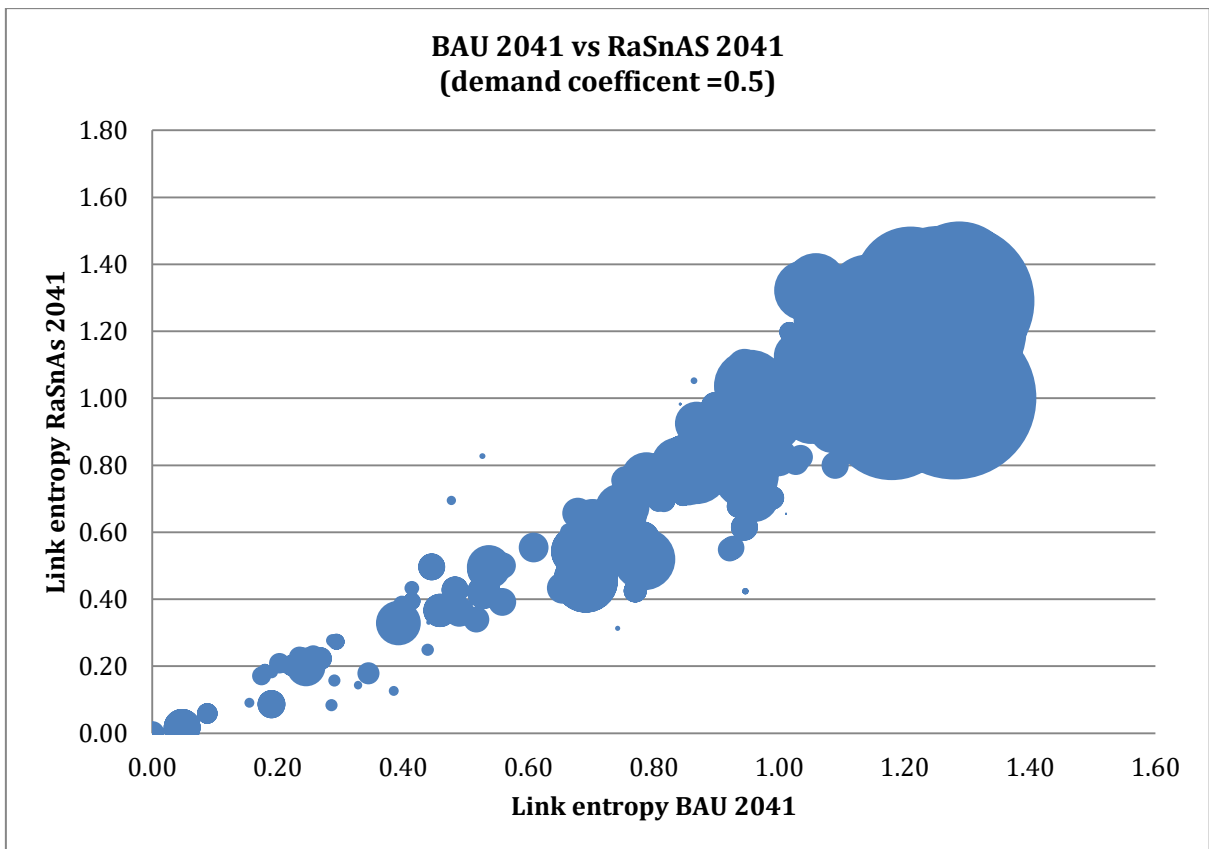


Figure 5-62 Link entropy between BAU 2041 and RaSnAS 2041 scenario, with demand coefficient decreased to 0.5

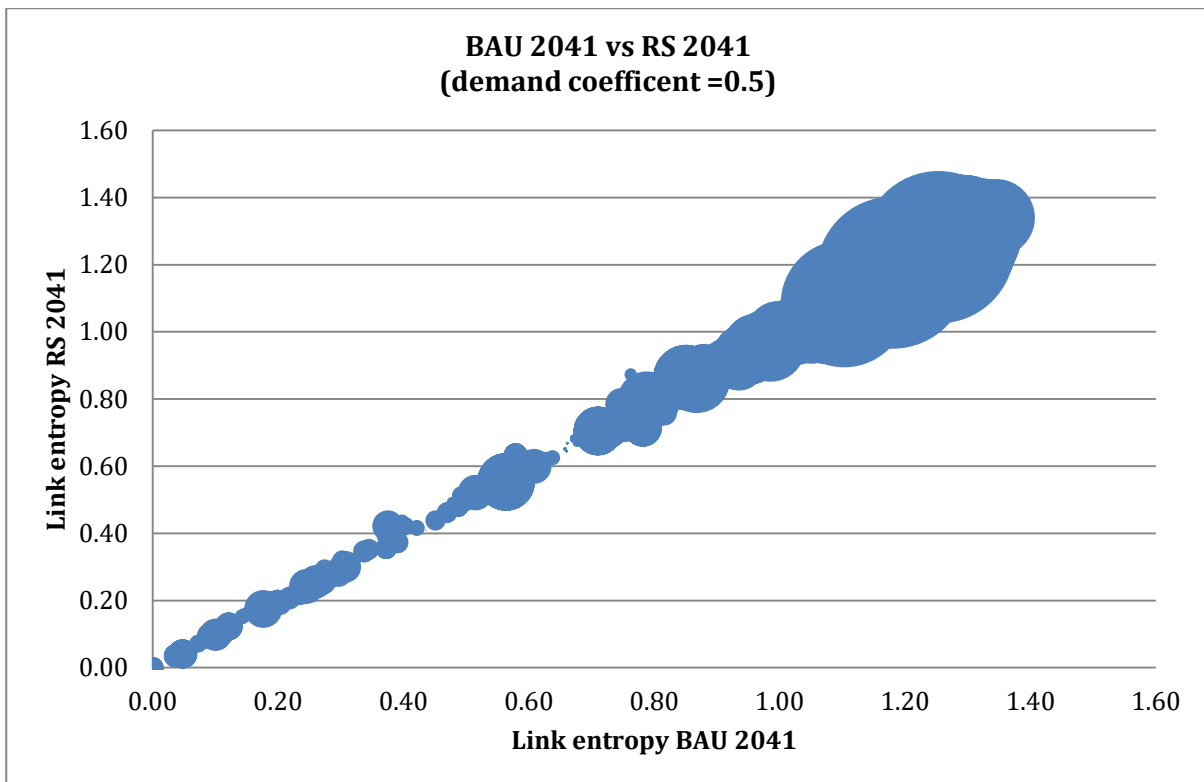


Figure 5-63 Link entropy between BAU 2041 and RS 2041 scenario, with demand coefficient decreased to 0.5

A last set of parameters chosen for the sensitivity analysis are the weighting parameters assumed in Equation 3.19. These parameters are chosen because of the uncertainties in the values adopted in the model. The weightings relating to comments of both restaurant and shopping activities are assumed to be 0.5, although it is possible that the weighting may diverge from this middle range. In the sensitivity analysis, the weightings relating to comments on restaurants and shopping have been set to 0.7 and 0.3 respectively. The resultant weighted link entropy for each scenario is summarised in table below. The weighted entropy values of all the scenarios remain around 1.2. This confirms that the general behaviour of the model do not change. All the chosen parameters above do not affect the broad conclusion reached.

Scenario	Existing 2013	BAU 2041	RaSnAS 2041	RS 2041
Base run (Weightings are both 0.5)	1.2134	1.2120	1.2067	1.2115
Weightings changed to 0.7 and 0.3	1.2138	1.2121	1.2068	1.2115

Table 5-20 Weighted link entropy comparison with change in weighting parameters

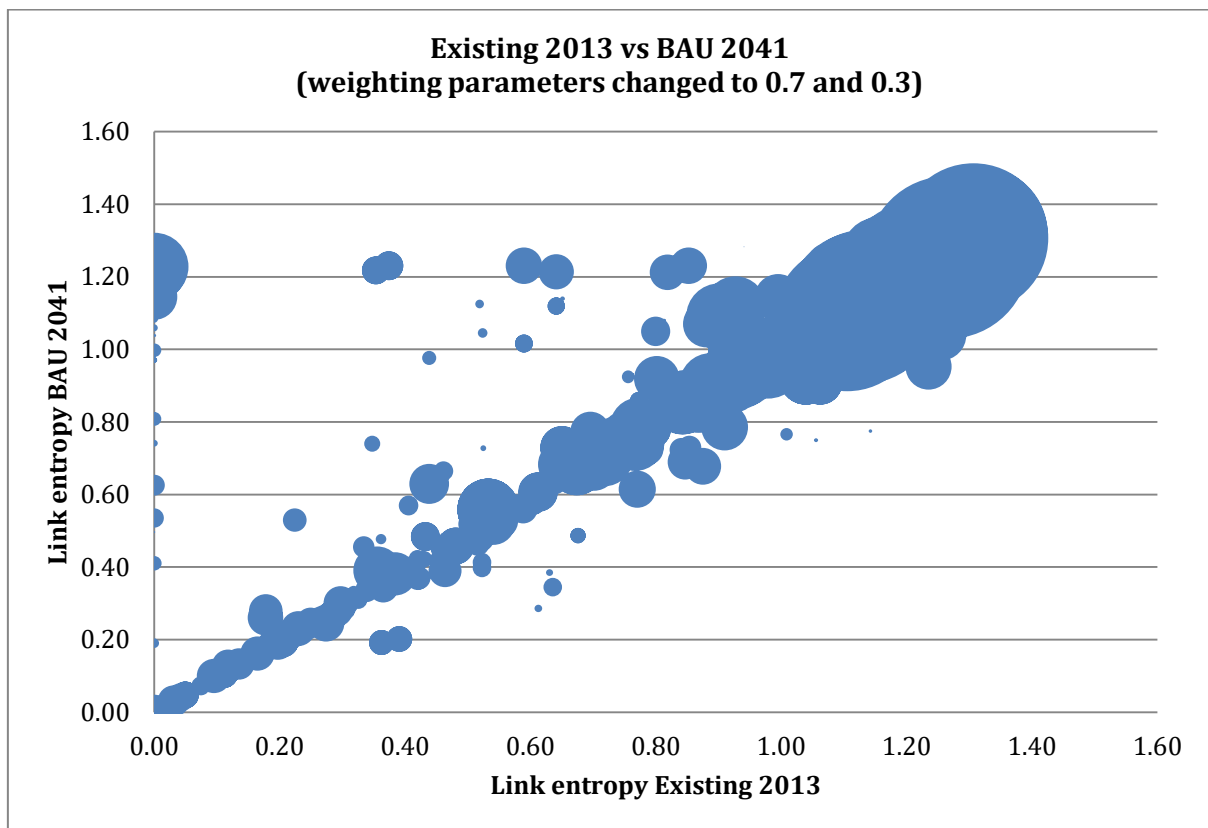


Figure 5-64 Link entropy between Existing 2013 and BAU 2041 scenario, with weighting parameters changed to 0.7 and 0.3

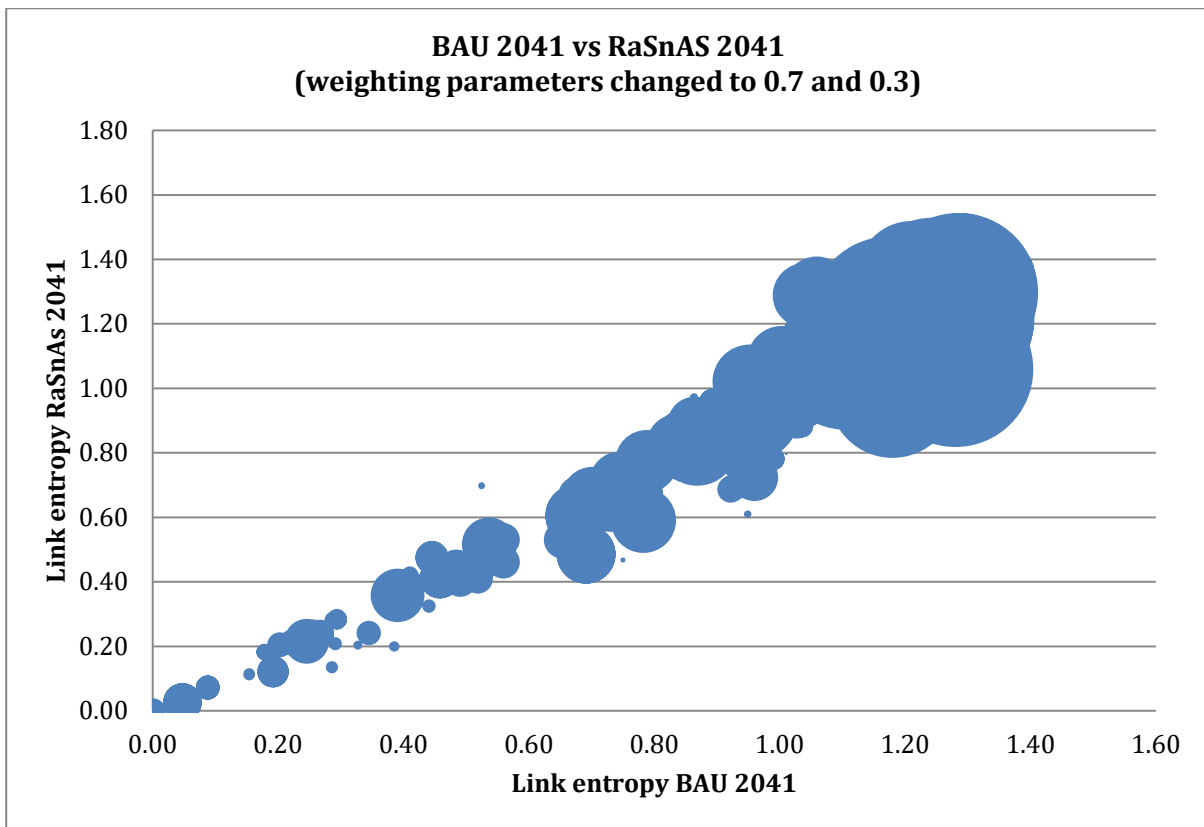


Figure 5-65 Link entropy between BAU 2041 and RaSnAS 2041 scenario, with weighting parameters changed to 0.7 and 0.3

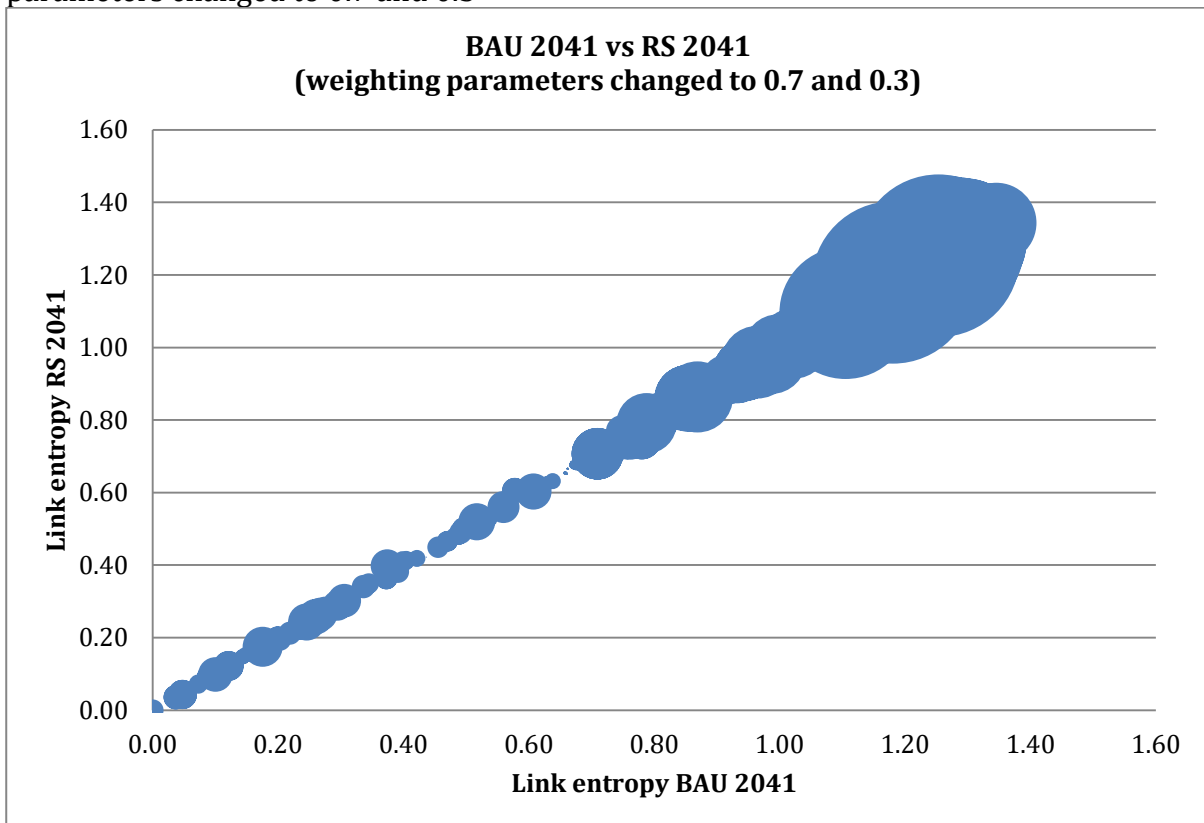


Figure 5-66 Link entropy between BAU 2041 and RS 2041 scenario, with weighting parameters changed to 0.7 and 0.3

## **Chapter 6 CONCLUSIONS**

In this dissertation, a new modelling approach has been established, which specifically addresses the current gap in research literature regarding discretionary travel outside the AM peak hour/period. New online and social media data sources have been used for model design, calibration and validation alongside traditional land use and transport data, which has helped to break the persistent data barrier that has hitherto hampered efforts to model discretionary travel in general. The model is built on the integrated land use and transport model software platform MEPLAN, while the simple and direct style of scenario tests is adopted from the land use and transport interaction model SIMULACRA. This means that the travel demand and traffic forecasts which are central to strategic economic, social and environmental assessments of transport interventions can be obtained in a robust way. The travel demand and traffic forecasts thus account comprehensively for the interactions among transport and land-use trends. It is hoped that the work presented in this dissertation serves as a new approach to test the long-term visions for alternative travel demand management, transport investment and urban masterplanning scenarios.

The methods and algorithms have been tested in a case study of Taichung. The results suggest that the new approach developed in this dissertation not only has made it much cheaper and faster to develop a robust travel demand model for all time periods of the day, but also fill a gap in the modelling of new, emerging patterns of travel, particularly those associate with the night economy. Such analyses could be of critical importance in improving the performance of the transport system in terms of safety, economic efficiency, air quality, and carbon reduction given the long lead times to plan and deliver transport infrastructure investments.

In this concluding chapter, we first discuss the findings and insights in the model development process and the model scenario tests. We then consider the strengths and weaknesses of the model system, and further developments that will be beneficial for academic and policy research.

### **6.1 Findings and insights**

In the order of the research work presented in this dissertation, we summarise the findings from the analyses of the social media data, the calibration and validation of the land use and strategic transport model, the predictions for the 2041 BAU scenario which represents a continuation of current demographic trend with no significant land use changes, and the tests of the alternative land use scenarios.

The use of social media data opens up the opportunity for improving trip generation model and distribution model for discretionary trips. The data obtained from online social media sites has streamlined the process of obtaining valuable new land use data which plug a gap in traditional data sources. The number of comments scraped from IPeen and TripAdvisor has helped establish the relative attractiveness of each zone and successfully highlight the attractions such as small shops and vendors which are difficult to quantify with the conventional survey methods. New types of accommodation provided on the emerging sharing platform such as Airbnb have helped to complement the government statistics on travellers' accommodation choices. The data collection and analysis methods also point to the possibility of establishing continuous monitoring of land use trends and provide regular updates for land use and transport modelling.

The estimation of congested road speeds by utilising the current version of Google Map Directions for 2013 show that such new data sources are a welcome new input which can be used to address otherwise costly procedures such as obtaining congested road speeds at the city scale and at different times of the day. Overall, the validation exercise for the congested speeds suggests that the proposed method is capable of providing a satisfactory estimation of the road link speeds across a network the size of Taichung. These congested link speeds produce estimated travel times for different time periods for the sampled routes that cover a wide range of types of roads and that are more likely to experience night time traffic due to the proximity of commercial centres which usually offers night time activities. The estimated travel times compare well with more sporadic observations that are obtainable from traditional traffic monitoring sources.

The overall performance of the strategic transport model for existing 2013 case would seem in general satisfactory. Both the interzonal and intrazonal networks that have been introduced to the model are working as intended, with the congested road speeds playing a key part in rapid model calibration eliminating the need to iterate between travel demand matrix estimation and the production of acceptably accurate congested road travel times. For the conventional travel purposes, the model has been used successfully to represent well the observed patterns of trip volumes by trip purpose, distance band distribution and mode shares. For the night market related travel, the modelled mode shares to Feng-chia precinct have been compared well with the observed data. The model results can be further tested for other night market clusters when such observed data become available.



The future scenarios have made use of the estimated 2013 congested road link speeds. This implies that Taichung manages to achieve reasonable road speeds through a combination of road investments, bus services consolidation, regional railway and metro line expansions and other transport improvements. This is based on the assumption that under ordinary circumstances, a city will tackle traffic congestion and adapt to traffic congestion. Certainly, this is not the only road traffic speed scenario that can be tested – the model is set up for all the travel speeds to vary – but it serves as an important benchmark for considering future planning of transport infrastructure and land use distribution. The BAU 2041 scenario suggest that if the road conditions remain the same as in 2013 without demand management measures, the all-day passenger trip volume is likely to rise by 2%, and trip-km by 3%. In terms trip purposes, all trip purposes will increase by 3% apart from the night time trips which will reduce by 18%. In terms of time periods, travel demand during the AM peak period will increase by 3%, but will decrease by 3% during the evening. This is also true for the RaSnAS 2041 scenario, when the airport site regeneration scheme becomes fully fledged, the total number of travel demand either by trip purpose or by time period will stay the same as that under the BAU 2041. However, the area closer to the airport site will experience a very big shift in travel demand because the airport site will attract all types of trips from other areas. Overall, the night time trips to the airport site will increase by 413% and trip-km by 500%. The Feng-chia precinct sitting next to the airport site will be impacted the most by the development of the airport site. The overall trips to and from Feng-chia will decrease by 4% while the trip-km will decrease by 8%. This means that the airport site regeneration will crowd out some of the night market activities otherwise served by Feng-chia, but the night time activities in the expanded commercial precinct will grow significantly.

For the RS 2041 scenario, the overall travel demand does not change very significantly, as expected. The most obvious change in demand occurs at the subcentres when trips of all types will increase by at most 12% at the expense of the trips going to the rest of the study area. Under this and other future scenarios, the upgrade of current railway network will not attract many trip volumes as intended. The mode share of railway will only be 1% for all trip types under all three future scenarios. This is because that this land use scenario continues the road-based development that has been occurring and the railway investment initiative is unlikely to be well supported by the relatively poor land use and transport coordination.

The research shows that the distribution of land use activities has a critical influence on travel and the choice of travel modes. Mixed land use area, such as the regenerated airport site, can improve walking accessibility for the area and the nearby areas. More alternative land use scenarios can be advised to optimise such effects.

## **6.2 Strengths, weaknesses and further development of the model**

The model design is comprehensive in its potential to address a wide range of policy initiatives. Its key strength lies in the wide range of behavioural responses that it represents. For instance, it can represent the changes in the land use activities that generate and attract travel, as well as the distribution of trips across the city among all time periods of the day. It can consider the changes in land use patterns within its land use and travel demand module. This is a unique strength that complements well other shorter term operational traffic forecasting models that may be in use in a city. Moreover, the inclusion of other time periods than the AM peak in the model makes it feasible to coordinate the land use pattern around transport infrastructure throughout the day rather than blindly providing more transport infrastructures for a single peak hour. The framework of the land use and strategic transport model is able to accumulate further data such as more temporal social media data and real-time traffic feeds in Taichung so that the evidence base can be enhanced.

To achieve a comprehensive urban activity and modal coverage while retaining computational feasibility, the model sacrifices some spatial detail through the design of relatively large model zones. This means the model is complementary to spatially detailed assignment models. The granularity of spatial representation can be improved through either an increase in the number of model zones for the study area or an implementation of adaptive zoning (see Hagen-Zanker and Jin, 2012a; 2012b) in the future.

The relatively large zone sizes may cause some concern over the precision of road link loadings. This is because the above practical reason for specifying large model zones leads to a significant proportion of traffic to be modelled on intrazonal links. Although the model results cover the mode choice behaviour across all travel through an intelligent intrazonal band modelling, the road link level forecasts for local traffic planning in particular neighbourhoods need to be used with care. There have been methods developed to convert intrazonal traffic onto interzonal road links, but such methods are suitable for specific road network configurations and are resource intensive. There is

scope to improve the model through a finer zoning map or an application of adaptive zoning as above, which can be implemented using standard methods already available.

The calibration for the night time activities is based on data that are available for Feng-chia precinct. There is a scope to improve the calibration process by obtaining more detailed data for other commercial centres such as mode share for going to other commercial centres.

The potential agglomeration effect which may be brought about by the regeneration of the airport site is only touched upon with the sensitivity test by increasing the attractiveness of night time activities in line with the new job opportunities. It would be beneficial in the future if the model is linked to a spatial economic model which is able to consider this effect on the land or rent price for a mixed land use site such as the airport site and the potential price adjustment of the services and goods in the nearby Feng-chia precinct. Social media data such as IPeen has the potential to benefit this aspect of model design as it contains the average spend of each reviewer on each shop. It may also be beneficial to scrape the social media data for a longer period of time covering the time of the development of the airport site so the agglomeration effect can be monitored.

The strategic transport network with congested speeds estimated with Google Map Directions are validated based on data from Google MAP and the comparison is made for the overall travel time along a route as opposed to for each individual link. Therefore, there is room to improve the validation exercise by collecting the link level speed or travel time from other sources. There are many gaps in the current statistics and surveys which limit the model design, calibration and validation. During the process of developing the model, new smart data sources, such as the Taichung real-time traffic information, have emerged. However due to the site still being at its initial stage, the server is not stable and data range only limits to major highway links which are not in the scope of the research. Therefore, it is hoped that in the near future the site can provide more satisfactory data so they can contribute to the improvement of the strategic transport model.

For the upgraded rail networks, the current model makes use of average link transit times rather than timetabled transit services. The MEPLAN implementation of the model provides the option to upgrade the coding using transit lines, which may be helpful for modelling e.g. complex metro service operations in the future. The bike sharing service in

Taichung is not included in the model. This service, though currently of a very small scale, could have the potential to impact on travel demand especially the discretionary travel as well as helping enable energy saving and carbon reduction. So there is a scope to include the bike sharing service in the model which may be significant if such operations expand in the future.

The model is not used in this dissertation to test the feedback of transport improvements on land use patterns. In the future scenario tests, model generated road congestion could be used as opposed to assuming a constant 2013 road travel times. This means solving the congested road travel times through iterating between the strategic transport model and land use model. This dissertation has established a framework for doing so. The current travel demand and traffic forecasts are focused on medium to long term impacts, where the traffic condition assumptions, model precision and granularity appear acceptable. However, the model methodology and structure set up in this can be extended in future work through enhanced data availability and extended land use-transport model iterations to enable fuller investigations into the initiatives that involve close coordination of land use and transport measures at the local traffic scheme level, such as in policy consulting work.

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## Appendix 1 MODEL ZONING SYSTEM

	District	MEPLAN zone	Number of household	Area (km2)
Urban core of Taichung	Central	126	2039	0.22
		134	2162	0.25
		127	2136	0.20
		137	1951	0.29
	East	117	1925	0.23
		122	3212	1.46
		124	3157	0.32
		143	2719	0.33
		150	2296	0.40
		119	1858	0.38
		132	1083	0.32
		140	2270	1.04
		146	2319	0.93
		133	1545	0.46
		139	1586	0.60
		151	2003	0.61
	West	98	2620	0.41
		114	2226	0.73
		121	2775	0.54
		135	3949	0.63
		136	2330	0.36
		138	3163	0.55
		107	3498	0.74
		120	6263	0.59
		118	2972	0.38
		141	9682	0.78
		131	1738	0.27
		142	2415	0.41
	South	148	2353	0.33
		152	5803	0.74
		149	3723	0.71
		162	10669	1.68
		154	3294	0.36
		161	3447	1.18
		153	5785	0.68
		165	5084	1.15
	North	157	2367	1.03
		89	6362	0.55
		90	7846	0.87
		105	3171	0.32
		103	4671	0.77
		99	6461	0.68

		110	1993	0.48
		116	1821	0.24
		95	6074	0.64
		100	4628	0.83
		106	5010	0.71
		115	2794	0.64
		112	3260	0.50
		123	1616	0.14
	Xi-tun	75	4498	1.21
		58	4137	9.32
		71	6053	2.05
		77	2276	1.13
		88	9689	1.05
		93	2831	1.53
		60	3446	5.14
		67	15455	12.42
		74	2854	0.95
		81	3811	0.35
		97	11098	1.17
		86	5857	0.56
		87	1585	2.34
	Nan-tun	108	18889	3.25
		113	3136	4.44
		129	13722	1.72
		128	4678	1.31
		91	9261	16.82
		144	5151	3.91
	Bei-tun	79	2565	2.66
		82	8870	1.04
		92	6190	0.70
		78	7641	0.87
		66	3692	2.31
		76	2836	0.28
		80	3086	0.44
		73	2796	2.15
		70	2752	6.67
		57	2032	32.77
		68	2468	2.45
		96	5438	0.82
		62	9134	2.97
		63	5619	3.19
		72	6691	1.11
		83	6998	0.89
		85	7119	0.65
	Fengyuan	19	6665	7.24

The rest of Taichung		18	6972	6.67
		21	6125	16.62
		31	2088	0.38
		27	2240	0.37
		30	5170	1.27
		39	7235	5.04
		34	7321	2.63
		36	1148	0.35
		38	3848	0.79
		32	2122	0.29
	Dongshi	8	7660	36.60
		13	8953	68.67
	Dajia	1	6721	36.67
		3	15540	22.10
	Qingshui	9	6293	35.09
		12	5630	7.54
		14	8779	4.48
		10	1853	7.89
		6	2994	19.24
	Shalu	26	3886	3.16
		41	4706	7.75
		40	2070	0.73
		23	1197	9.55
		25	2414	5.81
		49	1947	2.24
		54	4205	8.57
		45	3675	2.24
	Wuqi	24	2841	3.28
		35	4536	2.62
		42	2426	5.55
		20	3818	1.29
		29	3633	3.91
		15	0	8.47
	Houli	5	7996	30.09
		7	7022	27.16
	Shengang	16	10960	14.02
		11	7673	22.15
	Tanzi	59	4794	1.12
		46	1858	1.00
		61	4107	1.17
		64	8181	1.23
		53	2155	10.52
		52	3089	2.99
		55	8403	4.74
		48	2908	3.12

	Daya	37	5394	3.25
		28	2445	4.63
		33	3300	4.30
		47	2557	9.07
		44	1854	3.65
		43	7426	6.67
		51	6237	1.44
	Xinshe	22	7316	84.33
	Shigang	17	5075	17.87
	Waibu	4	9112	41.86
	Daan	2	5338	28.93
	Wuri	159	1055	3.76
		174	4851	5.10
		145	2880	5.90
		167	4668	1.97
		169	4731	1.12
		182	4105	24.67
	Dadu	84	10257	18.56
		109	6360	19.59
	Longjing	69	8183	6.38
		50	8387	21.70
		56	6158	11.97
	Wufeng	197	4795	3.00
		188	1511	5.54
		204	3009	8.98
		200	2746	3.60
		211	1261	4.50
		213	1624	12.22
		198	3722	58.60
	Taiping	94	8649	97.24
		101	10070	7.58
		104	7076	1.95
		147	5258	2.21
		155	2196	2.46
		111	12947	2.26
		130	3895	3.03
		156	8044	1.69
	Dali	163	4548	1.01
		170	5796	0.79
		173	7360	1.65
		184	4982	5.10
		177	6201	1.13
		164	6684	1.64
		168	8230	1.47
		172	1244	2.00
		178	5466	2.63

		185	8639	1.76
		180	1750	4.15
		179	1630	1.57
		187	4781	4.24
Outside of Taichung	Zhanghuashi	176	4204	11.96
		171	1595	3.33
		191	2434	4.44
		183	8676	2.29
		189	4481	1.45
		193	5665	0.73
		199	3322	0.50
		202	5348	1.49
		203	4172	0.63
		209	4948	3.92
		192	1060	2.99
		205	6023	2.76
		196	1517	12.57
		186	3439	2.44
		175	871	3.03
		194	3865	5.05
		208	5617	1.06
		195	2683	1.49
		190	3496	0.62
		210	1777	1.74
		207	1196	1.19
	ZhanghuaLugang	158	6625	22.03
		181	8948	19.44
		206	8719	3.04
	ZhanghuaHemei	102	7457	17.60
		160	9026	13.96
		166	7860	6.56
	ZhanghuaBeidou	253	10450	19.79
	ZhanghuaYuanlin	233	8163	22.69
		237	4029	1.52
		239	4428	1.73
		244	7367	4.22
		240	2367	0.86
		241	4328	0.80
		236	2967	3.20
		246	3304	4.54
	ZhanghuaXihu	234	15972	30.93
	ZhanghuaTianzhong	252	13364	34.35
	ZhanghuaXianxi	125	4324	13.43
	ZhanghuaShengang	65	9370	28.14

	ZhanghuaFuxing	218	3155	12.98
		214	4403	8.53
		212	1916	7.76
		223	2119	13.45
		216	1051	6.78
	ZhanghuaXiushui	201	2128	7.17
		217	4646	9.27
		224	3345	12.72
	ZhanghuaHuatan	219	2475	14.06
		221	4318	8.83
		222	2635	3.99
		215	4060	8.86
	ZhanghuaFenyuan	220	7441	37.19
	ZhanghuaDacun	230	3842	13.57
		231	3220	10.83
		228	3682	6.48
	ZhanghuaPuxin	235	9374	20.92
	ZhanghuaYongjing	247	11024	20.09
	ZhanghuaPuyan	225	10054	38.93
	ZhanghuaShetou	248	12976	35.80
	ZhanghuaTianwei	249	8630	24.66
	NantouNantoushi	245	8569	20.17
		243	11202	27.46
		251	4043	10.11
		242	5449	7.38
		250	5060	7.13
	NantouCaotun	226	10446	73.38
		227	3667	7.35
		238	5490	4.52
		229	7800	16.32
		232	5678	2.28

## Appendix 2 NETWORK LINK TYPES

Highway link types for AM period

Cod e	Capacity unit	Road description
1	pcu/hr	Highway_divided, 2 lane per direction_AM
2	pcu/hr	Highway_divided, 3 lane per direction_AM
5	pcu/hr	Expressway_divided, 2 lane per direction_AM
6	pcu/hr	Expressway_divided, 3 lane per direction_AM
11	pcu/hr	Ramp_1 lane per direction_AM
12	pcu/hr	Ramp_2 lane per direction_AM
13	pcu/hr	Urban road - Low Interference_undivided, 1 lane per dirction_AM
14	pcu/hr	Urban road - Low Interference_undivided, 2 lane per dirction_AM
15	pcu/hr	Urban road - Low Interference_undivided, 3 lane per dirction_AM
18	pcu/hr	Urban road - Low Interference_divided, 2 lane per dirction_AM
19	pcu/hr	Urban road - Low Interference_divided, 3 lane per dirction_AM
20	pcu/hr	Urban road - Low Interference_divided, 4 lane per dirction_AM
21	pcu/hr	Urban road - Low Interference_divided, 5 lane per dirction_AM
22	pcu/hr	Urban road - Median Interference_undivided, 1 lane per directon_AM
23	pcu/hr	Urban road - Median Interference_undivided, 2 lane per directon_AM
24	pcu/hr	Urban road - Median Interference_undivided, 3 lane per directon_AM
25	pcu/hr	Urban road - Median Interference_undivided, 4 lane per directon_AM
27	pcu/hr	Urban road - Median Interference_divided, 2 lane per directon_AM
28	pcu/hr	Urban road - Median Interference_divided, 3 lane per directon_AM
29	pcu/hr	Urban road - Median Interference_divided, 4 lane per directon_AM
30	pcu/hr	Urban road - Median Interference_divided, 5 lane per directon_AM
31	pcu/hr	Urban road - High Interference_undivided, 1 lane per direction_AM
32	pcu/hr	Urban road - High Interference_undivided, 2 lane per direction_AM
35	pcu/hr	Urban road - High Interference_divided, 1 lane per direction_AM
36	pcu/hr	Urban road - High Interference_divided, 2 lane per direction_AM
37	pcu/hr	Urban road - High Interference_divided, 3 lane per direction_AM
40	pcu/hr	Rural road - Plain_undivided, 1 lane per direction_AM
41	pcu/hr	Rural road - Plain_undivided, 2 lane per direction_AM
45	pcu/hr	Rural road - Plain_divided, 2 lane per direction_AM
46	pcu/hr	Rural road - Plain_divided, 3 lane per direction_AM
47	pcu/hr	Rural road - Plain_divided, 4 lane per direction_AM



48	pcu/hr	Rural road - Plain_divided, 5 lane per direction_AM
49	pcu/hr	Rural road - Hill_undivided, 1 lane per direction_AM
50	pcu/hr	Rural road - Hill_undivided, 2 lane per direction_AM
51	pcu/hr	Rural road - Hill_undivided, 3 lane per direction_AM
54	pcu/hr	Rural road - Hill_divided, 2 lane per direction_AM
60	pcu/hr	Urban lane_undivided, 1 lane per direction_AM
70	pcu/hr	Urban lane_undivided, 2 lane per direction_AM

#### Highway link types for Interpeak period

Cod e	Capacity unit	Road description
101	pcu/hr	Highway_divided, 2 lane per direction_Inter
102	pcu/hr	Highway_divided, 3 lane per direction_Inter
105	pcu/hr	Expressway_divided, 2 lane per direction_Inter
106	pcu/hr	Expressway_divided, 3 lane per direction_Inter
111	pcu/hr	Ramp_1 lane per direction_Inter
112	pcu/hr	Ramp_2 lane per direction_Inter
113	pcu/hr	Urban road - Low Interference_undivided, 1 lane per direction_Inter
114	pcu/hr	Urban road - Low Interference_undivided, 2 lane per direction_Inter
115	pcu/hr	Urban road - Low Interference_undivided, 3 lane per direction_Inter
118	pcu/hr	Urban road - Low Interference_divided, 2 lane per direction_Inter
119	pcu/hr	Urban road - Low Interference_divided, 3 lane per direction_Inter
120	pcu/hr	Urban road - Low Interference_divided, 4 lane per direction_Inter
121	pcu/hr	Urban road - Low Interference_divided, 5 lane per direction _Inter
122	pcu/hr	Urban road - Median Interference_undivided, 1 lane per direction _Inter
123	pcu/hr	Urban road - Median Interference_undivided, 2 lane per direction _Inter
124	pcu/hr	Urban road - Median Interference_undivided, 3 lane per direction _Inter
125	pcu/hr	Urban road - Median Interference_undivided, 4 lane per direction _Inter
127	pcu/hr	Urban road - Median Interference_divided, 2 lane per direction _Inter
128	pcu/hr	Urban road - Median Interference_divided, 3 lane per direction _Inter
129	pcu/hr	Urban road - Median Interference_divided, 4 lane per direction _Inter

130	pcu/hr	Urban road - Median Interference_divided, 5 lane per direction _ Inter
131	pcu/hr	Urban road - High Interference_undivided, 1 lane per direction _ Inter
132	pcu/hr	Urban road - High Interference_undivided, 2 lane per direction _ Inter
135	pcu/hr	Urban road - High Interference_divided, 1 lane per direction _ Inter
136	pcu/hr	Urban road - High Interference_divided, 2 lane per direction _ Inter
137	pcu/hr	Urban road - High Interference_divided, 3 lane per direction _ Inter
140	pcu/hr	Rural road - Plain_undivided, 1 lane per direction _ Inter
141	pcu/hr	Rural road - Plain_undivided, 2 lane per direction _ Inter
145	pcu/hr	Rural road - Plain_divided, 2 lane per direction _ Inter
146	pcu/hr	Rural road - Plain_divided, 3 lane per direction _ Inter
147	pcu/hr	Rural road - Plain_divided, 4 lane per direction _ Inter
148	pcu/hr	Rural road - Plain_divided, 5 lane per direction _ Inter
149	pcu/hr	Rural road - Hill_undivided, 1 lane per direction _ Inter
150	pcu/hr	Rural road - Hill_undivided, 2 lane per direction _ Inter
151	pcu/hr	Rural road - Hill_undivided, 3 lane per direction _ Inter
154	pcu/hr	Rural road - Hill_divided, 2 lane per direction _ Inter
160	pcu/hr	Urban lane_undivided, 1 lane per direction _ Inter
170	pcu/hr	Urban lane_undivided, 2 lane per direction _ Inter

#### Highway link types for PM period

Cod e	Capacity unit	Road description
201	pcu/hr	Highway_divided, 2 lane per direction_ PM
202	pcu/hr	Highway_divided, 3 lane per direction_ PM
205	pcu/hr	Expressway_divided, 2 lane per direction_ PM
206	pcu/hr	Expressway_divided, 3 lane per direction_ PM
211	pcu/hr	Ramp_1 lane per direction_ PM
212	pcu/hr	Ramp_2 lane per direction_ PM
213	pcu/hr	Urban road - Low Interference_undivided, 1 lane per direction_ PM
214	pcu/hr	Urban road - Low Interference_undivided, 2 lane per direction_ PM
215	pcu/hr	Urban road - Low Interference_undivided, 3 lane per direction_ PM
218	pcu/hr	Urban road - Low Interference_divided, 2 lane per direction_ PM
219	pcu/hr	Urban road - Low Interference_divided, 3 lane per direction_ PM
220	pcu/hr	Urban road - Low Interference_divided, 4 lane per direction_ PM
221	pcu/hr	Urban road - Low Interference_divided, 5 lane per direction _ PM

222	pcu/hr	Urban road - Median Interference_undivided, 1 lane per direction _ PM
223	pcu/hr	Urban road - Median Interference_undivided, 2 lane per direction _ PM
224	pcu/hr	Urban road - Median Interference_undivided, 3 lane per direction _ PM
225	pcu/hr	Urban road - Median Interference_undivided, 4 lane per direction _ PM
227	pcu/hr	Urban road - Median Interference_divided, 2 lane per direction _ PM
228	pcu/hr	Urban road - Median Interference_divided, 3 lane per direction _ PM
229	pcu/hr	Urban road - Median Interference_divided, 4 lane per direction _ PM
230	pcu/hr	Urban road - Median Interference_divided, 5 lane per direction _ PM
231	pcu/hr	Urban road - High Interference_undivided, 1 lane per direction _ PM
232	pcu/hr	Urban road - High Interference_undivided, 2 lane per direction _ PM
235	pcu/hr	Urban road - High Interference_divided, 1 lane per direction _ PM
236	pcu/hr	Urban road - High Interference_divided, 2 lane per direction _ PM
237	pcu/hr	Urban road - High Interference_divided, 3 lane per direction _ PM
240	pcu/hr	Rural road - Plain_undivided, 1 lane per direction _ PM
241	pcu/hr	Rural road - Plain_undivided, 2 lane per direction _ PM
245	pcu/hr	Rural road - Plain_divided, 2 lane per direction _ PM
246	pcu/hr	Rural road - Plain_divided, 3 lane per direction _ PM
247	pcu/hr	Rural road - Plain_divided, 4 lane per direction _ PM
248	pcu/hr	Rural road - Plain_divided, 5 lane per direction _ PM
249	pcu/hr	Rural road - Hill_undivided, 1 lane per direction _ PM
250	pcu/hr	Rural road - Hill_undivided, 2 lane per direction _ PM
251	pcu/hr	Rural road - Hill_undivided, 3 lane per direction _ PM
254	pcu/hr	Rural road - Hill_divided, 2 lane per direction _ PM
260	pcu/hr	Urban lane_undivided, 1 lane per direction _ PM
270	pcu/hr	Urban lane_undivided, 2 lane per direction _ PM

#### Highway link types for Evening period

Cod e	Capacity unit	Road description
301	pcu/hr	Highway_divided, 2 lane per direction_ Evening
302	pcu/hr	Highway_divided, 3 lane per direction_ Evening
305	pcu/hr	Expressway_divided, 2 lane per direction_ Evening
306	pcu/hr	Expressway_divided, 3 lane per direction_ Evening
311	pcu/hr	Ramp_1 lane per direction_ Evening

312	pcu/hr	Ramp_2 lane per direction_Evening
313	pcu/hr	Urban road - Low Interference_undivided, 1 lane per direction_Evening
314	pcu/hr	Urban road - Low Interference_undivided, 2 lane per direction_Evening
315	pcu/hr	Urban road - Low Interference_undivided, 3 lane per direction_Evening
318	pcu/hr	Urban road - Low Interference_divided, 2 lane per direction_Evening
319	pcu/hr	Urban road - Low Interference_divided, 3 lane per direction_Evening
320	pcu/hr	Urban road - Low Interference_divided, 4 lane per direction_Evening
321	pcu/hr	Urban road - Low Interference_divided, 5 lane per direction _Evening
322	pcu/hr	Urban road - Median Interference_undivided, 1 lane per direction _Evening
323	pcu/hr	Urban road - Median Interference_undivided, 2 lane per direction _Evening
324	pcu/hr	Urban road - Median Interference_undivided, 3 lane per direction _Evening
325	pcu/hr	Urban road - Median Interference_undivided, 4 lane per direction _Evening
327	pcu/hr	Urban road - Median Interference_divided, 2 lane per direction _Evening
328	pcu/hr	Urban road - Median Interference_divided, 3 lane per direction _Evening
329	pcu/hr	Urban road - Median Interference_divided, 4 lane per direction _Evening
330	pcu/hr	Urban road - Median Interference_divided, 5 lane per direction _Evening
331	pcu/hr	Urban road - High Interference_undivided, 1 lane per direction _Evening
332	pcu/hr	Urban road - High Interference_undivided, 2 lane per direction _Evening
335	pcu/hr	Urban road - High Interference_divided, 1 lane per direction _Evening
336	pcu/hr	Urban road - High Interference_divided, 2 lane per direction _Evening
337	pcu/hr	Urban road - High Interference_divided, 3 lane per direction _Evening
340	pcu/hr	Rural road - Plain_undivided, 1 lane per direction _Evening
341	pcu/hr	Rural road - Plain_undivided, 2 lane per direction _Evening
345	pcu/hr	Rural road - Plain_divided, 2 lane per direction _Evening
346	pcu/hr	Rural road - Plain_divided, 3 lane per direction _Evening
347	pcu/hr	Rural road - Plain_divided, 4 lane per direction _Evening
348	pcu/hr	Rural road - Plain_divided, 5 lane per direction _Evening
349	pcu/hr	Rural road - Hill_undivided, 1 lane per direction _Evening

350	pcu/hr	Rural road - Hill_undivided, 2 lane per direction _ Evening
351	pcu/hr	Rural road - Hill_undivided, 3 lane per direction _ Evening
354	pcu/hr	Rural road - Hill_divided, 2 lane per direction _ Evening
360	pcu/hr	Urban lane_undivided, 1 lane per direction _ Evening
370	pcu/hr	Urban lane_undivided, 2 lane per direction _ Evening

### Appendix 3 CONVERSION RATE

AM		Inter		PM		Evening		Road decription
Cod e	MUPerC U	Cod e	MUPerC U	Cod e	UTB	Cod e	MUPerC U	
1	55.65	101	57.74	201	60.91	301	55.19	Highway
2	55.65	102	57.74	202	60.91	302	55.19	
5	63.09	105	66.18	205	75.08	305	61.03	Expressway
6	63.09	106		206		306		
11	53.61	111	55.01	211	56.39	311	54.48	Ramp
12	53.61	112		212		312		
13	111.99	113	127.85	213	150.98	313	107.39	Urban road - Low Interference
14	111.99	114	127.85	214	150.98	314	107.39	
15	111.99	115	127.85	215	150.98	315	107.39	
18	111.99	118	127.85	218	150.98	318	107.39	
19	111.99	119	127.85	219	150.98	319	107.39	
20	111.99	120	127.85	220	150.98	320	107.39	
21	111.99	121	127.85	221	150.98	321	107.39	
22	108.04	122	128.88	222	157.96	322	105.56	Urban road - Median Interference
23	108.04	123	128.88	223	157.96	323	105.56	
24	108.04	124	128.88	224	157.96	324	105.56	
25	108.04	125	128.88	225	157.96	325	105.56	
27	108.04	127	128.88	227	157.96	327	105.56	
28	108.04	128	128.88	228	157.96	328	105.56	
29	108.04	129	128.88	229	157.96	329	105.56	
30	108.04	130	128.88	230	157.96	330	105.56	
31	85.73	131	98.86	231	109.59	331	84.82	Urban road - High Interference
32	85.73	132	98.86	232	109.59	332	84.82	
35	85.73	135	98.86	235	109.59	335	84.82	

36	85.73	136	98.86	236	109.5 9	336	84.82	
37	85.73	137	98.86	237	109.5 9	337	84.82	
40	124.29	140	132.42	240	139.0 0	340	110.89	Rural road - Plain
41	124.29	141	132.42	241	139.0 0	341	110.89	
45	124.29	145	132.42	245	139.0 0	345	110.89	
46	124.29	146	132.42	246	139.0 0	346	110.89	
47	124.29	147	132.42	247	139.0 0	347	110.89	
48	124.29	148	132.42	248	139.0 0	348	110.89	
49	67.29	149	68.88	249	69.88	349	67.46	Rural road - Hill
50	67.29	150	68.88	250	69.88	350	67.46	
51	67.29	151	68.88	251	69.88	351	67.46	
54	67.29	154	68.88	254	69.88	354	67.46	
60	123.50	160	138.93	260	147.6 7	360	116.29	Other urban road
70	123.50	170	138.93	270	147.6 7	370	116.29	
666	108.91	-	-	-	-	-	-	Access road to centroid

## Appendix 4 TRANSPORT MODES DEFINITION

Flow (Travel demand segment)	User Mode Code	Description	Network mode	Description	Link type
HBW_Inter, HBE_Inter, HBO_Inter, NHB_Inter, Nmarket_Inter	6	Car for Inter period travellers	110	Car for Inter	101 to 170
			91	Access for car	666
	7	Bus for Inter period travellers	120	Bus for Inter	113 to 170
			92	Access for bus	666
	8	Walk for Inter period travellers	130	Walk for Inter	113 to 170
			93	Access for walking	666
	9	Cycle for Inter period travellers	140	Cycle for Inter	113 to 170
			94	Access for cycling	666
	10	Motorcycle for Inter period travellers	141	Mortorcycle for Inter	113 to 170
			95	Access for motorcycle	666
	72	Rail for Inter period travellers	150	Rail for Inter	903
			93	Access for walking	666
			121	Feeder bus for Inter	113 to 170, 901, 902
HBW_PM, HBE_PM, HBO_PM, NHB_PM, Nmarket_PM	61	Car for PM period travellers	210	Car for PM	201 to 270
			91	Access for car	666
	62	Bus for PM period travellers	220	Bus for PM	213 to 270
			92	Access for bus	666
	63	Walk for PM period travellers	230	Walk for PM	213 to 270
			93	Access for walking	666
	64	Cycle for PM period travellers	240	Cycle for PM	213 to 270
			94	Access for cycling	666
	65	Motorcycle for PM period travellers	241	Mortorcycle for PM	213 to 270
			95	Access for motorcycle	666
	73	Rail for PM period travellers	250	Rail for PM	903
			93	Access for walking	666
			221	Feeder bus for PM	213 to 270, 901, 902
HBW_Evening, HBE_Evening, HBO_Evening, NHB_Evening, Nmarket_Evening	66	Car for Evening period travellers	310	Car for Evening	301 to 370
			91	Access for car	666
	67	Bus for Evening period travellers	320	Bus for Evening	313 to 370
			92	Access for bus	666
	68	Walk for Evening period travellers	330	Walk for Evening	313 to 370
			93	Access for walking	666
	69	Cycle for Evening period travellers	340	Cycle for Evening	313 to 370
			94	Access for cycling	666
	70	Motorcycle for Evening period	341	Mortorcycle for Evening	313 to 370
			95	Access for motorcycle	666
	74	Rail for Evening period travellers	350	Rail for Evening	903
			93	Access for walking	666
			321	Feeder bus for Evening	313 to 370, 901, 902
All flows	11-19	Intrazonal car travel by 9 distance bands	61-69	Intrazonal travel for car	4001-4009, 4011-4019
			91	Access for car	666
	21-29	Intrazonal bus travel by 9 distance bands	71-79	Intrazonal travel for bus	4001-4009, 4011-4019
			92	Access for bus	666
	31-34	Intrazonal walking by 4 distance bands	81-84	Intrazonal travel for walking	4001-4004, 4011-4014
			93	Access for walking	666
	41-45	Intrazonal cycling by 5 distance bands	85-89	Intrazonal travel for cycling	4001-4005, 4011-4015
			94	Access for cycling	666
	51-59	Intrazonal motorcycle travel by 9 distance	101-109	Intrazonal travel for motorcycle	4001-4009, 4011-4019
			95	Access for motorcycle	666



## Appendix 5 USER MODE CONSTANTS

Flow	Network M	User Mode Con	Flow	Network M	User Mode Con	Flow	Network M	User Mode Con	Flow	Network M	User Mode Cons
1	-4	-50	2	-4	-25	3	-4	-20	4	-4	-25
	-5	3		-5	-5		-5	-12		-5	-1
	-6	-12		-6	-5		-6	-12		-6	-5
	-7	0		-7	0		-7	0		-7	0
	-8	0		-8	0		-8	0		-8	0
	-9	0		-9	0		-9	0		-9	0
	-10	0		-10	0		-10	0		-10	0
	-11	0		-11	0		-11	0		-11	0
	-12	0		-12	0		-12	0		-12	0
	1	-25		1	-10		1	-20		1	-20
	2	0		2	-5		2	0		2	-18
	3	0		3	-5		3	-12		3	-10
	4	25		4	25		4	20		4	20
	5	-25		5	-6		5	-25		5	-10
	11	-15		11	-10		11	-20		11	-20
	12	-25		12	-10		12	-20		12	-20
	13	-25		13	-10		13	-20		13	-20
	14	-25		14	-10		14	-20		14	-20
	15	-25		15	-10		15	-20		15	-20
	16	-25		16	-10		16	-20		16	-20
	17	-25		17	-10		17	-20		17	-20
	18	-25		18	-10		18	-20		18	-20
	19	-25		19	-10		19	-20		19	-20
	21	0		21	-5		21	0		21	-18
	22	0		22	-5		22	0		22	-18
	23	0		23	-5		23	0		23	-18
	24	0		24	-5		24	0		24	-18
	25	0		25	-5		25	0		25	-18
	26	0		26	-5		26	0		26	-18
	27	0		27	-5		27	0		27	-18
	28	0		28	-5		28	0		28	-18
	29	0		29	-5		29	0		29	-18
	31	0		31	-5		31	-12		31	-10
	32	0		32	-5		32	-12		32	-10
	33	0		33	-5		33	-12		33	-10
	34	0		34	-5		34	-12		34	-10
	41	25		41	25		41	20		41	20
	42	25		42	25		42	20		42	20
	43	25		43	25		43	20		43	20
	44	25		44	25		44	20		44	20
	45	25		45	25		45	20		45	20
	51	-25		51	-6		51	-25		51	-10
	52	-25		52	-6		52	-25		52	-10
	53	-25		53	-6		53	-25		53	-10
	54	-25		54	-6		54	-25		54	-10
	55	-25		55	-6		55	-25		55	-10
	56	-25		56	-6		56	-25		56	-10
	57	-25		57	-6		57	-25		57	-10
	58	-25		58	-6		58	-25		58	-10
	59	-25		59	-6		59	-25		59	-10
	71	0		71			71	0		71	0

Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant
6	-4	-50	7	-4	-25	8	-4	-20	9	-4	-25
	-5	3		-5	-5		-5	-12		-5	-1
	-6	-12		-6	-5		-6	-12		-6	-5
	-7			-7			-7			-7	
	-8			-8			-8			-8	
	-9			-9			-9			-9	
	-10			-10			-10			-10	
	-11			-11			-11			-11	
	-12			-12			-12			-12	
	6	-25		6	-10		6	-20		6	-20
	7			7	-5		7			7	-18
	8			8	-5		8	-12		8	-10
	9	25		9	25		9	20		9	20
	10	-25		10	-6		10	-25		10	-10
	11	-25		11	-10		11	-20		11	-20
	12	-25		12	-10		12	-20		12	-20
	13	-25		13	-10		13	-20		13	-20
	14	-25		14	-10		14	-20		14	-20
	15	-25		15	-10		15	-20		15	-20
	16	-25		16	-10		16	-20		16	-20
	17	-25		17	-10		17	-20		17	-20
	18	-25		18	-10		18	-20		18	-20
	19	-25		19	-10		19	-20		19	-20
	21			21	-5		21			21	-18
	22			22	-5		22			22	-18
	23			23	-5		23			23	-18
	24			24	-5		24			24	-18
	25			25	-5		25			25	-18
	26			26	-5		26			26	-18
	27			27	-5		27			27	-18
	28			28	-5		28			28	-18
	29			29	-5		29			29	-18
	31			31	-5		31	-12		31	-10
	32			32	-5		32	-12		32	-10
	33			33	-5		33	-12		33	-10
	34			34	-5		34	-12		34	-10
	41	25		41	25		41	20		41	20
	42	25		42	25		42	20		42	20
	43	25		43	25		43	20		43	20
	44	25		44	25		44	20		44	20
	45	25		45	25		45	20		45	20
	51	-25		51	-6		51	-25		51	-10
	52	-25		52	-6		52	-25		52	-10
	53	-25		53	-6		53	-25		53	-10
	54	-25		54	-6		54	-25		54	-10
	55	-25		55	-6		55	-25		55	-10
	56	-25		56	-6		56	-25		56	-10
	57	-25		57	-6		57	-25		57	-10
	58	-25		58	-6		58	-25		58	-10
	59	-25		59	-6		59	-25		59	-10
	72			72			72			72	

Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant
11	-4	-50	12	-4	-25	13	-4	-20	14	-4	-25	15	-4	-20
	-5	3		-5	-5		-5	-12		-5	-1		-5	-5
	-6	-12		-6	-5		-6	-12		-6	-5		-6	-5
	-7			-7			-7			-7			-7	
	-8			-8			-8			-8			-8	
	-9			-9			-9			-9			-9	
	-10			-10			-10			-10			-10	
	-11			-11			-11			-11			-11	
	-12			-12			-12			-12			-12	
	61	-25		61	-10		61	-20		61	-20		61	-15
	62			62	-5		62			62	-18		62	
	63			63	-5		63	-12		63	-10		63	
	64	25		64	25		64	20		64	20		64	
	65	-25		65	-6		65	-25		65	-10		65	-10
	11	-25		11	-10		11	-20		11	-20		11	-15
	12	-25		12	-10		12	-20		12	-20		12	-15
	13	-25		13	-10		13	-20		13	-20		13	-15
	14	-25		14	-10		14	-20		14	-20		14	-15
	15	-25		15	-10		15	-20		15	-20		15	-15
	16	-25		16	-10		16	-20		16	-20		16	-15
	17	-25		17	-10		17	-20		17	-20		17	-15
	18	-25		18	-10		18	-20		18	-20		18	-15
	19	-25		19	-10		19	-20		19	-20		19	-15
	21			21	-5		21			21	-18		21	
	22			22	-5		22			22	-18		22	
	23			23	-5		23			23	-18		23	
	24			24	-5		24			24	-18		24	
	25			25	-5		25			25	-18		25	
	26			26	-5		26			26	-18		26	
	27			27	-5		27			27	-18		27	
	28			28	-5		28			28	-18		28	
	29			29	-5		29			29	-18		29	
	31			31	-5		31	-12		31	-10		31	
	32			32	-5		32	-12		32	-10		32	
	33			33	-5		33	-12		33	-10		33	
	34			34	-5		34	-12		34	-10		34	
	41	25		41	25		41	20		41	20		41	
	42	25		42	25		42	20		42	20		42	
	43	25		43	25		43	20		43	20		43	
	44	25		44	25		44	20		44	20		44	
	45	25		45	25		45	20		45	20		45	
	51	-25		51	-6		51	-25		51	-10		51	-10
	52	-25		52	-6		52	-25		52	-10		52	-10
	53	-25		53	-6		53	-25		53	-10		53	-10
	54	-25		54	-6		54	-25		54	-10		54	-10
	55	-25		55	-6		55	-25		55	-10		55	-10
	56	-25		56	-6		56	-25		56	-10		56	-10
	57	-25		57	-6		57	-25		57	-10		57	-10
	58	-25		58	-6		58	-25		58	-10		58	-10
	59	-25		59	-6		59	-25		59	-10		59	-10
	73			73			73			73			73	



Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant	Flow	Network Mode	User Mode Constant
16	-4	-50	17	-4	-25	18	-4	-20	19	-4	-25	20	-4	-20
	-5	3		-5	-5		-5	-12		-5	-1		-5	-5
	-6	-12		-6	-5		-6	-12		-6	-5		-6	-5
	-7			-7			-7			-7			-7	
	-8			-8			-8			-8			-8	
	-9			-9			-9			-9			-9	
	-10			-10			-10			-10			-10	
	-11			-11			-11			-11			-11	
	-12			-12			-12			-12			-12	
	66	-25		66	-10		66	-20		66	-20		66	-15
	67			67	-5		67			67	-18		67	
	68			68	-5		68	-12		68	-10		68	
	69	25		69	25		69	20		69	20		69	
	70	-25		70	-6		70	-25		70	-10		70	-10
	11	-25		11	-10		11	-20		11	-20		11	-15
	12	-25		12	-10		12	-20		12	-20		12	-15
	13	-25		13	-10		13	-20		13	-20		13	-15
	14	-25		14	-10		14	-20		14	-20		14	-15
	15	-25		15	-10		15	-20		15	-20		15	-15
	16	-25		16	-10		16	-20		16	-20		16	-15
	17	-25		17	-10		17	-20		17	-20		17	-15
	18	-25		18	-10		18	-20		18	-20		18	-15
	19	-25		19	-10		19	-20		19	-20		19	-15
	21			21	-5		21			21	-18		21	
	22			22	-5		22			22	-18		22	
	23			23	-5		23			23	-18		23	
	24			24	-5		24			24	-18		24	
	25			25	-5		25			25	-18		25	
	26			26	-5		26			26	-18		26	
	27			27	-5		27			27	-18		27	
	28			28	-5		28			28	-18		28	
	29			29	-5		29			29	-18		29	
	31			31	-5		31	-12		31	-10		31	
	32			32	-5		32	-12		32	-10		32	
	33			33	-5		33	-12		33	-10		33	
	34			34	-5		34	-12		34	-10		34	
	41	25		41	25		41	20		41	20		41	
	42	25		42	25		42	20		42	20		42	
	43	25		43	25		43	20		43	20		43	
	44	25		44	25		44	20		44	20		44	
	45	25		45	25		45	20		45	20		45	
	51	-25		51	-6		51	-25		51	-10		51	-10
	52	-25		52	-6		52	-25		52	-10		52	-10
	53	-25		53	-6		53	-25		53	-10		53	-10
	54	-25		54	-6		54	-25		54	-10		54	-10
	55	-25		55	-6		55	-25		55	-10		55	-10
	56	-25		56	-6		56	-25		56	-10		56	-10
	57	-25		57	-6		57	-25		57	-10		57	-10
	58	-25		58	-6		58	-25		58	-10		58	-10
	59	-25		59	-6		59	-25		59	-10		59	-10
	74			74			74			74			74	

## Appendix 6 LAND USE ASSUMPTION

Number of Households					
District	Zone group	Existing 2013	BAU 2041	RaSnAS 2041	RS 2041
Central	Taichung railway station	6249	-10%	-11%	-11%
	The rest of the district	2039	-10%	-11%	-11%
East	Taichung railway rear station	2719	1%	0%	0%
	The rest of the district	23254	1%	0%	0%
West	Calligraphy Greenway	12536	5%	4%	3%
	Jing-ming Street	4846	5%	4%	3%
	Fine Art Museum Precinct	13631	5%	4%	3%
	The rest of the district	12618	5%	4%	3%
North	Yi-zhong Street Precinct	2794	-7%	-8%	-9%
	Jian-xing Road	6461	-7%	-8%	-9%
	The rest of the district	46452	-7%	-8%	-9%
Xi-tun	Feng-chia Precinct	7352	27%	49%	25%
	New City Hall Precinct	11098	27%	26%	25%
	The rest of the district	55140	27%	42%	25%
South		42525	21%	19%	19%
Nan-tun		54837	32%	30%	30%
Bei-tun		85927	18%	17%	16%
Feng-yuan		50934	11%	10%	22%
Da-li		67311	15%	14%	13%
Tai-ping		58134	7%	6%	6%
Dong-shi		16613	-8%	-8%	-9%
Da-jia		22261	4%	4%	3%
Qing-shui		25549	10%	9%	20%
Sha-lu		24100	25%	24%	56%
Wu-qi		17254	14%	13%	12%
Hou-li		15018	0%	0%	-1%
Shen-gang		18633	5%	4%	3%
Tan-zi		35495	15%	14%	13%
Da-ya		29214	17%	16%	15%
Xin-she		7316	-3%	-3%	-4%
Shi-gang		5075	1%	1%	0%
Wai-bu		9112	6%	5%	5%
Da-an		5338	0%	-1%	-2%
Wu-ri		22290	11%	11%	24%
Da-du		16617	1%	1%	0%
Long-jing		22728	23%	22%	21%
Wu-feng		18668	11%	10%	9%
Zhang-hua & Nan-tou		389357	8%	7%	6%
Total		1267493	11.2%	11.2%	11.2%

Number of residents					
District	Zone group	Existing 2013	BAU 2041	RaSnAS 2041	RS 2041
Central	Taichung railway station	17432	-13%	-14%	-13%
	The rest of the district	5040	-13%	-14%	-13%
East	Taichung railway rear station	8105	-5%	-5%	-5%
	The rest of the district	65864	-5%	-5%	-5%
West	Calligraphy Greenway	31363	-2%	-2%	-2%
	Jing-ming Street	24557	-2%	-2%	-2%
	Fine Art Museum Precinct	26082	-2%	-2%	-2%
	The rest of the district	35363	-2%	-2%	-2%
North	Yi-zhong Street Precinct	4206	-12%	-13%	-12%
	Jian-xing Road	16443	-12%	-13%	-12%
	The rest of the district	126990	-12%	-13%	-12%
Xi-tun	Feng-chia Precinct	21943	17%	36%	16%
	New City Hall Precinct	26919	17%	16%	16%
	The rest of the district	157674	17%	31%	16%
South		113659	13%	12%	13%
Nan-tun		153779	23%	23%	23%
Bei-tun		246880	11%	10%	11%
Feng-yuan		165433	3%	2%	5%
Da-li		197716	9%	8%	8%
Tai-ping		172965	1%	0%	0%
Dong-shi		53259	-13%	-14%	-14%
Da-jia		78387	-3%	-4%	-4%
Qing-shui		85620	1%	0%	2%
Sha-lu		81534	10%	9%	22%
Wu-qi		55262	9%	8%	9%
Hou-li		54287	-6%	-7%	-7%
Shen-gang		63753	-2%	-3%	-3%
Tan-zi		100481	7%	6%	7%
Da-ya		89825	11%	10%	11%
Xin-she		25637	-8%	-8%	-8%
Shi-gang		15976	-4%	-5%	-5%
Wai-bu		32051	-2%	-3%	-3%
Da-an		20308	-6%	-7%	-7%
Wu-ri		68709	2%	1%	3%
Da-du		55725	-5%	-6%	-6%
Long-jing		74474	17%	17%	17%
Wu-feng		63975	3%	2%	3%
Zhang-hua & Nan-tou		1301080	1%	1%	1%
Total		3938756	3.8%	3.8%	3.8%

Number of trips generated					
District	Zone group	Existing 2013	BAU 2041	RaSnAS 2041	RS 2041
Central	Taichung railway station	35527	-10%	-11%	-11%
	The rest of the district	10515	-11%	-12%	-12%
East	Taichung railway rear station	15346	0%	-1%	-1%
	The rest of the district	120673	0%	-2%	-2%
West	Calligraphy Greenway	66898	3%	2%	2%
	Jing-ming Street	26755	2%	0%	0%
	Fine Art Museum Precinct	69304	4%	2%	2%
	The rest of the district	66869	3%	2%	2%
North	Yi-zhong Street Precinct	16186	-7%	-8%	-8%
	Jian-xing Road	33464	-8%	-9%	-10%
	The rest of the district	244613	-8%	-9%	-9%
Xi-tun	Feng-chia Precinct	41111	23%	57%	21%
	New City Hall Precinct	58322	24%	23%	22%
	The rest of the district	293228	24%	41%	22%
South	Taichung train station	221902	18%	17%	17%
Nan-tun		286041	29%	28%	27%
Bei-tun		446842	16%	14%	14%
Feng-yuan		263336	8%	7%	19%
Da-li		346528	13%	12%	11%
Tai-ping		298811	5%	4%	4%
Dong-shi		85016	-9%	-10%	-10%
Da-jia		116479	2%	1%	1%
Qing-shui		131593	7%	6%	17%
Sha-lu		127026	21%	20%	50%
Wu-qi		89067	12%	11%	10%
Hou-li		77504	-2%	-3%	-3%
Shen-gang		96539	3%	2%	1%
Tan-zi		181434	13%	12%	11%
Da-ya		150467	14%	13%	13%
Xin-she		37209	-5%	-5%	-6%
Shi-gang		25738	0%	-1%	-2%
Wai-bu		47056	4%	3%	2%
Da-an		27524	-3%	-3%	-4%
Wu-ri		114546	9%	8%	21%
Da-du		85238	-1%	-2%	-2%
Long-jing		116595	20%	19%	19%
Wu-feng		99518	8%	7%	7%
Zhang-hua & Nan-tou		2004203	6%	5%	4%
Total		6575022	8.953%	8.946%	8.946%

## Appendix 7 TRAVEL DEMAND OF FENG-CHIA PRECINCT AND THE REST OF THE STUDY AREA

Existing 2013								
Destination	Origin	Time period	Mode	Ave. distance	Ave. cost	Ave. time	Ave. disutility	FlowVol.
The rest of study area	The rest of study area	AM	Car	7.39	35.83	25.32	21.05	1,158,500
			Bus	7.90	0.00	52.84	46.36	441,900
			Walk	1.73	0.00	24.90	18.23	419,293
			Cycle	4.96	0.00	28.65	51.79	235,857
			Mcycle	5.09	10.59	21.75	6.63	2,483,600
The rest of study area	Feng-chia (zone 74)	AM	Car	8.52	48.03	30.44	28.01	2,039
			Bus	6.54	0.00	46.43	39.83	1,198
			Walk	2.75	0.00	37.08	30.02	590
			Cycle	5.16	0.00	32.18	54.99	449
			Mcycle	6.67	14.03	29.83	15.08	3,937
Feng-chia (zone 74)	The rest of study area	AM	Car	8.16	47.78	32.60	44.76	4,895
			Bus	7.98	0.00	52.13	46.91	7,289
			Walk	2.92	0.00	39.28	33.96	2,866
			Cycle	6.25	0.00	36.49	61.11	2,561
			Mcycle	7.15	15.69	32.07	30.83	12,389
Feng-chia (zone 74)	Feng-chia (zone 74)	AM	Car	0.95	19.71	26.46	24.82	93
			Bus	1.08	0.00	36.70	30.83	68
			Walk	0.72	0.00	12.33	6.77	592
			Cycle	1.33	0.00	12.22	36.30	130
			Mcycle	1.02	2.53	9.51	-5.48	1,720
The rest of study area	The rest of study area	IP	Car	6.94	33.11	25.36	19.56	423,325
			Bus	7.77	0.00	54.53	47.87	131,462
			Walk	1.80	0.00	25.87	17.09	143,700
			Cycle	4.96	0.00	28.77	50.53	84,823
			Mcycle	4.86	10.01	22.29	5.02	927,120
The rest of study area	Feng-chia (zone 74)	IP	Car	9.05	49.77	31.85	37.40	981
			Bus	7.55	0.00	52.21	46.46	771
			Walk	2.85	0.00	38.79	31.53	377



			Cycle	5.84	0.00	34.79	57.91	322
			Mcycl e	6.95	14.84	32.52	22.14	2,124
Feng-chia (zone 74)	The rest of study area	IP	Car	8.80	49.31	34.62	38.53	915
			Bus	7.20	0.00	52.30	46.59	712
			Walk	2.90	0.00	39.39	31.87	363
			Cycle	5.95	0.00	35.33	58.29	317
			Mcycl e	6.92	14.75	33.80	22.33	2,077
Feng-chia (zone 74)	Feng-chia (zone 74)	IP	Car	0.84	19.07	26.03	15.04	35
			Bus	1.08	0.00	36.67	29.93	12
			Walk	0.74	0.00	12.52	5.20	116
			Cycle	1.33	0.00	12.22	34.66	29
			Mcycl e	1.07	2.53	9.64	-10.20	527
The rest of study area	The rest of study area	PM	Car	6.98	34.19	26.20	21.97	1,207,000
			Bus	7.53	0.00	56.51	47.43	513,210
			Walk	1.73	0.00	24.85	18.09	520,518
			Cycle	5.31	0.00	30.15	53.70	300,021
			Mcycl e	4.98	10.57	23.74	10.84	2,323,400
The rest of study area	Feng-chia (zone 74)	PM	Car	9.35	50.10	33.28	49.97	5,376
			Bus	8.34	0.00	57.67	48.10	9,321
			Walk	2.97	0.00	40.10	34.22	3,743
			Cycle	6.54	0.00	37.68	62.46	3,460
			Mcycl e	7.05	15.63	35.00	35.85	12,901
Feng-chia (zone 74)	The rest of study area	PM	Car	9.48	48.53	36.34	45.96	3,116
			Bus	8.72	0.00	60.27	45.22	4,679
			Walk	2.79	0.00	37.97	30.83	1,751
			Cycle	6.65	0.00	38.10	62.54	1,500
			Mcycl e	6.93	14.91	36.11	31.16	6,566
Feng-chia (zone 74)	Feng-chia (zone 74)	PM	Car	0.95	19.00	26.46	22.95	250
			Bus	1.16	0.00	37.11	19.84	425
			Walk	0.75	0.00	12.65	4.53	1,724
			Cycle	1.33	0.00	12.22	33.79	413
			Mcycl e	1.11	2.63	9.79	-0.73	3,279

The rest of study area	The rest of study area	Eve	Car	5.98	29.43	22.79	17.08	410,218
			Bus	6.78	0.00	48.57	34.24	195,249
			Walk	1.44	0.00	21.30	13.01	192,767
			Cycle	3.89	0.00	24.23	47.02	84,631
			Mcycl e	4.81	9.93	20.12	6.21	833,249
The rest of study area	Feng-chia (zone 74)	Eve	Car	8.92	45.97	29.36	43.27	2,114
			Bus	9.54	0.00	53.20	35.36	4,096
			Walk	2.47	0.00	33.91	26.25	1,166
			Cycle	5.53	0.00	33.40	58.15	761
			Mcycl e	7.38	15.49	29.94	28.30	4,459
Feng-chia (zone 74)	The rest of study area	Eve	Car	8.69	43.13	32.26	42.02	1,273
			Bus	10.25	0.00	56.81	34.38	2,849
			Walk	2.29	0.00	31.76	22.59	720
			Cycle	5.68	0.00	33.85	58.35	421
			Mcycl e	7.22	14.64	31.19	25.90	2,669
Feng-chia (zone 74)	Feng-chia (zone 74)	Eve	Car	1.00	18.87	26.65	25.30	153
			Bus	1.18	0.00	37.20	17.76	380
			Walk	0.76	0.00	12.81	3.29	1,226
			Cycle	1.33	0.00	12.22	32.60	309
			Mcycl e	1.16	2.65	9.93	0.37	2,071

BAU 2041								
Destination	Origin	Time period	Mode	Ave. distance	Ave. cost	Ave. time	Ave. disutility	FlowVol.
The rest of the study area	The rest of the study area	AM	Car	7.50	36.34	25.32	21.19	1,182,400
			Bus	7.93	0.00	52.72	46.24	455,709
			Walk	1.77	0.00	25.13	18.46	429,403
			Cycle	5.00	0.00	28.70	51.83	242,609
			Mcycl e	5.09	10.60	21.79	6.67	2,538,400
			Rail	8.57	25.75	8.83	53.44	41,678

The rest of the study area	Feng-chia (zone 74)	AM	Car	8.16	46.8 3	30.7 3	27.81	2,368
			Bus	6.79	0.00	46.0 2	39.49	1,409
			Walk	3.38	0.00	38.2 8	31.23	781
			Cycle	5.50	0.00	30.5 9	53.41	571
			Mcycl e	6.56	13.8 6	29.9 5	15.09	4,503
			Rail	9.82	24.9 4	12.2 6	86.43	62
Feng-chia (zone 74)	The rest of the study area	AM	Car	7.54	45.4 6	32.4 1	43.71	5,455
			Bus	7.91	0.00	50.7 5	45.54	8,198
			Walk	3.34	0.00	37.6 4	32.33	4,136
			Cycle	6.19	0.00	33.3 1	57.92	3,169
			Mcycl e	6.79	14.9 5	31.6 6	30.01	13,494
			Rail	9.57	24.4 6	12.3 6	92.39	273
Feng-chia (zone 74)	Feng-chia (zone 74)	AM	Car	0.95	19.7 1	26.4 6	24.81	108
			Bus	1.08	0.00	36.7 0	30.84	79
			Walk	0.72	0.00	12.3 3	6.78	690
			Cycle	1.33	0.00	12.2 2	36.30	151
			Mcycl e	1.02	2.53	9.51	-5.50	2,008
The rest of the study area	The rest of the study area	IP	Car	7.05	33.6 4	25.3 9	19.78	432,396
			Bus	7.79	0.00	54.3 8	47.73	136,348
			Walk	1.85	0.00	26.1 6	17.38	147,789
			Cycle	5.01	0.00	28.8 2	50.59	87,779
			Mcycl e	4.87	10.0 2	22.3 6	5.09	949,417

			Rail	8.48	25.8 0	8.98	55.72	11,459
The rest of the study area	Feng-chia (zone 74)	IP	Car	8.62	48.2 4	31.8 3	36.62	1,094
			Bus	7.47	0.00	50.7 3	45.05	882
			Walk	3.31	0.00	37.8 0	30.59	530
			Cycle	5.98	0.00	32.0 3	55.14	403
			Mcycl e	6.65	14.2 5	32.1 3	21.32	2,379
			Rail	9.57	24.5 8	13.2 1	97.83	23
Feng-chia (zone 74)	The rest of the study area	IP	Car	8.47	48.0 3	34.5 6	38.03	1,018
			Bus	7.26	0.00	51.2 6	45.54	821
			Walk	3.43	0.00	39.0 0	31.57	507
			Cycle	6.08	0.00	32.8 0	55.73	400
			Mcycl e	6.66	14.2 4	33.6 8	21.93	2,306
			Rail	9.72	24.7 9	13.2 5	98.31	22
Feng-chia (zone 74)	Feng-chia (zone 74)	IP	Car	0.84	19.0 7	26.0 3	15.02	41
			Bus	1.08	0.00	36.6 6	29.95	14
			Walk	0.74	0.00	12.5 2	5.21	136
			Cycle	1.33	0.00	12.2 2	34.66	34
			Mcycl e	1.07	2.53	9.64	-10.21	615
The rest of the study area	The rest of the study area	PM	Car	7.17	35.1 5	26.3 2	22.27	1,211,000
			Bus	7.67	0.00	56.7 8	48.29	511,049
			Walk	1.78	0.00	25.3 0	18.65	515,478
			Cycle	5.41	0.00	30.4 4	54.01	302,889

			Mcycl e	5.01	10.6 4	23.9 0	10.88	2,342,300
			Rail	8.52	25.9 9	9.23	58.72	30,235
The rest of the study area	Feng- chia (zone 74)	PM	Car	8.42	46.9 1	32.9 6	48.31	6,061
			Bus	8.21	0.00	55.7 2	46.51	10,185
			Walk	3.40	0.00	38.5 2	32.80	5,125
			Cycle	6.58	0.00	34.5 6	59.32	4,103
			Mcycl e	6.64	14.7 9	34.0 5	34.34	13,972
			Rail	9.37	24.3 4	14.1 7	112.33	112
Feng-chia (zone 74)	The rest of the study area	PM	Car	9.26	48.2 2	36.3 8	45.09	3,420
			Bus	8.67	0.00	59.0 2	44.58	5,077
			Walk	3.40	0.00	38.8 7	31.99	2,250
			Cycle	6.77	0.00	35.8 2	60.23	1,792
			Mcycl e	6.69	14.4 9	36.0 9	30.45	7,164
			Rail	9.96	25.2 5	14.1 3	109.82	53
Feng-chia (zone 74)	Feng- chia (zone 74)	PM	Car	0.94	19.0 2	26.4 3	22.68	270
			Bus	1.16	0.00	37.1 0	20.17	441
			Walk	0.75	0.00	12.6 3	4.68	1,846
			Cycle	1.33	0.00	12.2 2	33.94	439
			Mcycl e	1.11	2.62	9.76	-0.94	3,576
The rest of the study area	The rest of the study area	Eve	Car	6.23	30.7 8	23.0 4	17.37	395,813
			Bus	7.09	0.00	49.1 1	36.01	179,645
			Walk	1.48	0.00	21.6 4	13.55	178,158

			Cycle	4.02	0.00	24.7 3	47.54	80,225
			Mcycl e	4.91	10.1 3	20.3 8	6.07	815,474
			Rail	8.47	25.5 8	8.73	53.47	12,067
The rest of the study area	Feng- chia (zone 74)	Eve	Car	8.19	43.7 3	29.3 9	41.87	2,301
			Bus	9.47	0.00	52.0 2	34.68	4,278
			Walk	3.00	0.00	34.6 9	27.37	1,458
			Cycle	5.66	0.00	31.0 6	55.79	887
			Mcycl e	7.04	14.8 6	29.5 6	27.40	4,681
			Rail	9.53	24.4 9	12.0 4	88.36	90
Feng-chia (zone 74)	The rest of the study area	Eve	Car	8.65	43.5 5	32.5 5	41.53	1,318
			Bus	10.39	0.00	56.1 6	34.07	2,941
			Walk	2.96	0.00	34.6 7	25.68	820
			Cycle	5.93	0.00	32.6 2	57.06	475
			Mcycl e	7.08	14.4 4	31.4 4	25.34	2,793
			Rail	10.15	25.4 6	12.0 3	89.43	45
Feng-chia (zone 74)	Feng- chia (zone 74)	Eve	Car	1.00	18.8 9	26.6 3	25.00	160
			Bus	1.18	0.00	37.1 9	17.84	385
			Walk	0.76	0.00	12.8 0	3.34	1,256
			Cycle	1.33	0.00	12.2 2	32.66	316
			Mcycl e	1.16	2.64	9.91	0.12	2,157
RaSnAS 2041								
Destination	Origin	Time perio d	Mode	Ave. distanc e	Ave. cost	Ave. time	Ave. disutilit y	FlowVol.
	The rest of the	AM	Car	7.61	36.8 7	25.5 7	21.70	1,175,400

The rest of the study area	study area		Bus	8.05	0.00	52.8 0	46.32	465,344
			Walk	1.83	0.00	25.2 8	18.63	429,640
			Cycle	5.09	0.00	28.9 0	52.03	244,467
			Mcycl e	5.18	10.7 8	22.1 3	7.12	2,520,200
			Rail	8.68	25.6 9	8.94	54.66	42,952
The rest of the study area	Feng-chia (zone 74)	AM	Car	6.55	40.9 3	28.7 9	23.58	2,314
			Bus	5.70	0.00	42.8 4	36.63	1,324
			Walk	2.44	0.00	26.5 9	19.79	1,199
			Cycle	4.27	0.00	24.1 9	47.17	615
			Mcycl e	5.31	11.4 2	27.1 5	11.21	4,371
			Rail	9.92	25.0 5	12.2 7	86.39	45
Feng-chia (zone 74)	The rest of study area	AM	Car	7.58	45.7 4	32.3 5	43.99	4,999
			Bus	8.02	0.00	51.0 7	45.92	7,623
			Walk	3.24	0.00	36.2 2	30.81	3,929
			Cycle	6.21	0.00	33.3 2	57.97	2,938
			Mcycl e	6.81	15.0 3	31.6 9	30.31	12,423
			Rail	9.69	24.6 0	12.3 8	92.73	249
Feng-chia (zone 74)	Feng-chia (zone 74)	AM	Car	0.94	19.7 7	26.4 2	25.60	84
			Bus	1.08	0.00	36.7 0	31.23	65
			Walk	0.72	0.00	12.3 0	7.08	565
			Cycle	1.33	0.00	12.2 2	36.66	121
			Mcycl e	1.01	2.53	9.47	-4.30	1,513
The rest of study area	The rest of study area	IP	Car	7.20	34.2 8	25.5 9	20.36	429,811

			Bus	7.96	0.00	54.5 1	47.87	140,499
			Walk	1.93	0.00	26.3 9	17.63	147,813
			Cycle	5.15	0.00	29.1 5	50.91	88,788
			Mcycl e	4.97	10.2 4	22.7 6	5.64	941,699
			Rail	8.64	25.7 6	9.17	57.59	11,506
The rest of the study area	Feng- chia (zone 74)	IP	Car	8.00	46.0 8	30.8 7	34.45	1,015
			Bus	7.31	0.00	50.1 5	44.69	796
			Walk	2.84	0.00	31.7 2	24.44	580
			Cycle	5.57	0.00	29.9 1	53.12	375
			Mcycl e	6.15	13.3 0	30.7 8	19.36	2,183
			Rail	9.69	24.7 1	13.2 3	97.98	19
Feng-chia (zone 74)	The rest of study area	IP	Car	7.72	45.4 9	33.1 2	35.15	957
			Bus	6.80	0.00	49.6 3	44.05	742
			Walk	2.75	0.00	30.4 2	22.54	609
			Cycle	5.46	0.00	29.5 8	52.54	377
			Mcycl e	6.04	13.0 7	31.9 2	19.41	2,130
			Rail	9.87	24.9 5	13.2 7	98.24	18
Feng-chia (zone 74)	Feng- chia (zone 74)	IP	Car	0.83	19.1 1	25.9 6	14.80	30
			Bus	1.07	0.00	36.6 2	30.54	10
			Walk	0.73	0.00	12.3 8	5.98	95
			Cycle	1.33	0.00	12.2 2	35.35	22
			Mcycl e	1.02	2.48	9.52	-9.48	401
The rest of study area	The rest of study area	PM	Car	7.31	35.7 6	26.4 5	22.68	1,204,700



			Bus	7.74	0.00	56.7 2	48.29	517,679
			Walk	1.83	0.00	25.4 4	18.81	515,548
			Cycle	5.47	0.00	30.5 4	54.11	304,509
			Mcycl e	5.08	10.7 9	24.1 8	11.25	2,323,700
			Rail	8.55	25.8 8	9.37	60.25	30,230
The rest of the study area	Feng- chia (zone 74)	PM	Car	7.74	44.4 9	31.8 8	45.99	6,078
			Bus	7.49	0.00	52.9 2	42.20	10,546
			Walk	2.98	0.00	32.6 5	26.00	6,137
			Cycle	6.24	0.00	32.7 7	57.56	4,088
			Mcycl e	6.21	13.9 2	32.7 9	32.66	13,831
			Rail	9.45	24.4 2	14.1 9	112.76	99
Feng-chia (zone 74)	The rest of study area	PM	Car	7.08	40.4 6	32.7 0	38.28	3,813
			Bus	6.86	0.00	51.7 6	35.45	5,886
			Walk	2.55	0.00	27.1 4	19.27	3,835
			Cycle	5.60	0.00	29.8 2	54.33	2,008
			Mcycl e	5.33	11.7 3	31.7 5	25.08	7,797
			Rail	9.97	25.2 3	14.1 6	110.41	43
Feng-chia (zone 74)	Feng- chia (zone 74)	PM	Car	0.95	19.0 3	26.4 3	23.23	220
			Bus	1.16	0.00	37.1 0	20.23	372
			Walk	0.75	0.00	12.6 2	4.76	1,557
			Cycle	1.33	0.00	12.2 2	34.02	368
			Mcycl e	1.11	2.63	9.76	-0.19	2,896
The rest of study area	The rest of study area	Eve	Car	6.34	31.2 8	23.1 5	17.69	392,431

			Bus	7.15	0.00	49.0 3	36.11	180,591
			Walk	1.53	0.00	21.7 7	13.70	177,151
			Cycle	4.09	0.00	24.8 5	47.67	80,228
			Mcycl e	4.98	10.2 8	20.6 1	6.37	808,221
			Rail	8.51	25.4 6	8.83	54.41	12,379
The rest of the study area	Feng- chia (zone 74)	Eve	Car	6.55	38.1 8	27.6 7	37.40	2,649
			Bus	7.32	0.00	46.0 0	26.91	5,156
			Walk	2.33	0.00	24.1 7	15.49	2,801
			Cycle	4.47	0.00	24.6 1	49.43	1,124
			Mcycl e	5.71	12.2 2	26.8 3	23.45	5,337
			Rail	9.60	24.5 3	12.0 7	88.41	76
Feng-chia (zone 74)	The rest of study area	Eve	Car	5.73	33.9 8	28.5 4	33.55	1,749
			Bus	7.32	0.00	47.0 5	24.17	3,819
			Walk	2.12	0.00	21.4 3	11.96	2,180
			Cycle	3.91	0.00	21.7 9	46.43	736
			Mcycl e	4.84	10.1 3	26.2 4	18.86	3,574
			Rail	10.21	25.4 7	12.0 8	89.47	33
Feng-chia (zone 74)	Feng- chia (zone 74)	Eve	Car	1.00	18.8 9	26.6 4	25.27	132
			Bus	1.18	0.00	37.1 9	17.84	325
			Walk	0.76	0.00	12.7 9	3.37	1,055
			Cycle	1.33	0.00	12.2 2	32.67	265
			Mcycl e	1.16	2.65	9.92	0.57	1,770